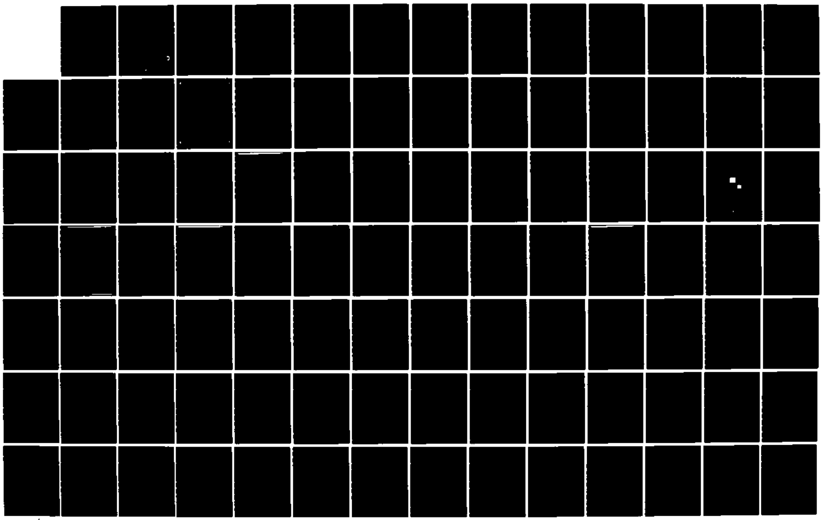
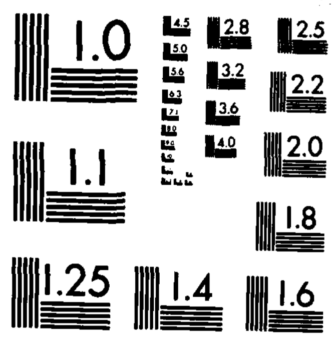
AD-A152 923 BENTHIC AND NEKTONIC STUDIES OF WINYAH BAY FOR THE PROPOSED CHANNEL DEEPE..(U) SOUTH CAROLINA WILDLIFE AND MARINE RESOURCES DEPT CHARLESTON M.. P M HINDE ET AL. 1/2

UNCLASSIFIED FEB 81 DACW60-80-C-0029 F/G 8/1 NL




1.0
2.8
2.5
3.2
2.2
3.6
2.0
1.1
4.0
1.8
1.25
1.4
1.6

CHARLESTON DISTRICT
U. S. ARMY CORPS OF ENGINEERS

CONTRACT #DACW60-80-C-0029

BENTHIC AND NEKTONIC STUDIES OF WINYAH BAY FOR THE PROPOSED CHANNEL DEEPENING PROJECT AND DREDGING OF ~~THE~~ WESTERN CHANNEL TURNING BASIN

by

Priscilla M. Hinde
Charles A. Wenner
Joseph Smith
Dale R. Calder

Marine Resources Division
South Carolina Wildlife and Marine Resources Department
Charleston, South Carolina

February 1981

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Figures (Con't)

SUMMARY

Benthic and nektonic studies of lower Winyah Bay and ~~the Winyah Bay~~ its entrance channel were conducted during October 1980 in order to determine the composition of the fauna and to assess the potential impacts of proposed dredging operations on the biota.

Three replicate grab samples were taken at each of 12 benthic sampling sites located either within, or adjacent to, the existing channel to Georgetown. In addition, qualitative samples of the epibenthos were taken with a modified oyster dredge. Fishes and decapod crustaceans were collected at each of six designated areas in three eight-minute trawl tows made at both high and low tides.

Hydrographic analyses of bottom water samples indicated that salinities ranged from mesohaline in the Western Channel and South Island reaches to euhaline in the Ocean Reach of the study area. Salinities in the former two reaches fluctuated considerably between tidal stages, ranging from mesohaline at low tide to euhaline at high tide. The natural stress imposed by such a highly variable salinity regime accounts for the low species richness and faunal abundances as well as for the numerical dominance by relatively few eurytopic species in the Western Channel and South Island reaches of Winyah Bay.

Cluster and nodal analyses of the fish and decapod fauna and of the macrobenthos suggest that salinity regime and substrate type are among the most important abiotic factors determining the composition of the fauna throughout the study area. Faunal assemblages in the Ocean Reach were generally characterized by a predominance of stenohaline marine species while those in the South Island and Western Channel reaches were largely comprised of euryhaline marine, euryhaline opportunistic and estuarine endemic species.

The occurrence of oyster shell and rocks at certain stations in lower Winyah Bay provided a number of microhabitats for a variety of sessile and motile epifaunal species. In addition, the higher abundances and greater species richness of infaunal organisms at these stations suggest that the hard substrates may also function as a refuge from predation by large motile predators.

The only difference in faunal composition between channel and bank stations which could reasonably be ascribed to an impact from previous dredging operations, was found at channel station CW03. p. iii The unusually silty sediments and overwhelming numerical dominance by a single opportunistic bivalve, *Mulinia lateralis*, suggest that dredging may have lowered current velocities within the entrance channel sufficiently to have changed a formerly dynamic hydrographic regime into a relatively quiescent, depositional one. This conclusion is strictly conjectural, however, since there is virtually no baseline information on benthic assemblages in this area.

The impact of future dredging operations on the macrobenthic of lower Winyah Bay would probably be greatest in those areas characterized by the presence of hard substrates which currently support a diverse assemblage of epifaunal species. The extent of community recovery in these areas would depend upon the presence of suitable substrates following dredging.

With respect to the infauna, those stenotopic species which comprise the fauna in the ocean reach of the study area would be expected to be most severely impacted by dredging since these species do not generally exhibit opportunistic life history strategies which would enable them to recolonize denuded substrates rapidly. Conversely, recovery of infaunal communities in the lower and middle reaches of Winyah Bay would probably be rapid since the inhabitants of such a highly variable environment are typically resilient in response to human disturbances.

Finally, because of their mobility, most fishes and decapod crustaceans should not experience any direct, adverse impact from dredging. A temporary reduction in fishes & crustaceans ~~their abundances~~ may result from the removal of benthic organisms which constitute the major food resource for demersal fish and crustaceans. Abundances would be expected to return to pre-dredging levels as the benthos recolonized denuded substrates, however.

INTRODUCTION

Winyah Bay and its four major tributaries, the Pee Dee, Black, Waccamaw, and Sampit Rivers, constitute one of the largest estuarine systems in South Carolina. The estuary is widely acknowledged as a vital and complex resource with respect to both the economy and ecology of the area. It provides shipping access to the port of Georgetown which ranks second in the state only to Charleston Harbor in volume of commercial traffic. Winyah Bay is also important as a habitat for penaeid shrimp, blue crab and a variety of commercial and sport finfish including flounder, spot, striped bass, and others.

Sedimentation in Winyah Bay has always been a problem due to the tremendous freshwater inflow from its major tributaries. The U. S. Soil Conservation Service estimated that 25,509,943 tons of soil are eroded each year throughout the watershed of which 1,000,000 tons of sediment are deposited in Winyah Bay annually. Data further indicate that most of the sediments reaching the bay originate below the last major reservoir on the Yadkin River, just north of the North Carolina state line (Conservation Foundation, 1980). The mass loading of sediments to the Winyah Bay system is excessive, largely because of inadequate soil conservation practices.

In addition, large quantities of sand are carried into the bay from the ocean on flood tides. Sediments tend to become trapped within the estuary as a consequence of the typically estuarine circulation patterns which characterize the hydrography of Winyah Bay. Siltation is particularly rapid in Georgetown Harbor since this is the approximate location of the critical interface between fresh and saltwater during periods of average freshwater inflow.

The rapid and excessive shoaling of Winyah Bay presents serious difficulties to the passage of large cargo vessels and threatens Georgetown's competitiveness as a commercial port. The U. S. Army Corps of Engineers currently maintains a 27-foot-deep, 18-mile-long channel from the mouth of Winyah Bay to Georgetown. Even at 27 feet, however, most large commercial vessels currently using Georgetown Harbor are unable to operate fully loaded maximum drafts at all tide stages. Consequently, consideration is being given both to deepening the existing channel and to relocating port facilities to an area seaward of the existing terminal. The most practical location for a new terminal appears to be at Esterville Plantation on the western shore of Winyah Bay, approximately nine miles south of Georgetown.

In October 1980, this study was undertaken by the South Carolina Wildlife and Marine Resources Department under contract with the U. S. Army Corps of Engineers in order to provide data on biological assemblages and bottom sediments within and immediately adjacent to the existing channel to Georgetown from its seaward limit to the site of the proposed terminal at Esterville Plantation. The main objective of this study was to evaluate the possible impacts of future dredging operations on resident fishes as well as on nektonic and benthic invertebrates. As a short-term study, however, this report does not constitute a comprehensive environmental impact study of the proposed channel-deepening/port-relocation project.

STUDY AREA

The Winyah Bay estuarine system lies in the Coastal Plain Province between the Cape Fear River Basin, North Carolina to the north and the Santee River Basin to the south. The estuary encompasses the lower reaches of the Pee Dee, Black, Waccamaw and Sampit Rivers, as well as Winyah Bay itself and numerous local tributaries. Within this region are 31,867 acres of coastal marshland (Tiner, 1977). Because of the strong freshwater influence from its major tributaries, freshwater marshes predominate. These account for 22,649 acres or 81% of the Winyah Bay wetlands. Brackish marshes comprise 4,915 acres or 18% of the marshes, while salt marshes occupy only 204 acres or less than 1% of the Winyah Bay wetlands.

The Winyah Bay region has a typically maritime climate with mild temperatures and abundant rainfall, especially in the spring and summer. The mean annual temperature is 67^{o}F and the mean annual rainfall is 50 inches. The area is generally frost-free from mid-March through mid-November (Conservation Foundation, 1980).

Economic development in and near Winyah Bay and its subestuaries has centered around agriculture, port activities and heavy industry, especially in the Georgetown area. Farming and forestry are more common in outlying regions. Major crops include corn, soybeans and tobacco. The major industrial facilities are the Georgetown Steel Company and the International Paper Corporation. The principal fishery resources are anadromous fish (shad, river herring, and sturgeon), penaeid shrimp, and blue crab. Winyah Bay's American shad and Atlantic sturgeon fisheries are two of the most important fisheries in the state, while the shrimp catch from Winyah Bay accounts for 10% of the total harvest for South Carolina. Recreational fishing activity is concentrated near the Winyah jetties, where species such as red drum, flounder, sea trout, tarpon, and sheepshead are caught. Striped bass are caught in the upper reaches of the bay and its tributaries.

The Winyah Bay area is characterized by an extremely diverse plant community, especially in the freshwater reaches. While vegetation varies markedly with elevation and salinity, it is generally dominated by emergent, narrow-leaved rushes, sedges and grasses. Smooth cordgrass dominates the saltmarshes, particularly the low marsh. Tree species include tag alder, bald cypress, ironwood, tupelo and black gum. These occur along natural levees and abandoned ricefield dikes (Tiner, 1977).

The fauna of Winyah Bay is also varied. In addition to the fishery resources already mentioned, a variety of waterfowl including ibis, heron and egrets use Pumpkin Seed Island in the widest reach of Winyah Bay as a major rookery. Beaches, especially along North Island, are utilized by species of sea turtles as nesting sites. Little is known about the benthos of Winyah Bay.

Evidence suggests that Winyah Bay may best be classified as "partially mixed" although it has been observed that conditions fluctuate greatly, especially at the extremes of the estuary (Bloomer, 1973). The location of the saltwater interface varies about four miles between high and low tides and, at high tide, may vary by as much as 16 miles depending on the freshwater inflow (Johnson, 1970). During periods of average freshwater inflow (c. 15,000 cfs.), the interface at high tide reaches mile 2.0 on the Black River and mile 5.0 on the Pee Dee and Waccamaw Rivers. The maximum upstream point at which there is a detectable tidal influence has been estimated to be river mile 82 for the Waccamaw River, mile 38 for the Pee Dee, and river mile 46 for the Black River. The Sampit River is tidal throughout its entire length.

these stations at different stages in the tidal cycle.

Bottom water temperatures ranged from a low of 16.1°C at station CW08 to a high of 19.8°C at station CW01 (Table 2). Temperatures were generally higher and less variable with depth at stations in the ocean reach (CW01 through CW05) than they were at stations located within the bay itself (CW06 through CW12). The lowest temperatures were recorded at shallow, near-shore stations CW08, CW10 and CW12, probably as a consequence of the rapid seasonal cooling of land runoff.

Dissolved oxygen levels in bottom water samples were invariably high, reflecting the well-mixed condition of the water column in the lower Winyah Bay area (Table 2). The lowest concentration (6.73 mg/l) was recorded at the deepest channel station, CW05.

Sediments at stations CW01, CW02, CW05, CW06 and CW07 consisted of greater than 90% sand-size particles (Table 3). The shell component, measured as % $CaCO_3$, comprised a substantial portion of the coarse fraction (25.2%) at station CW07, reflecting the presence of oyster shell and mussels.

Thus, both channel and bank stations in the ocean and lower bay reaches were characterized by primarily sandy sediments. Two exceptions to this generalization were stations CW03 and CW04. The former was a channel station with silty-clay sediments, while the latter was supposed to have been a bank station. However, the considerable depth (7.3 m) and seemingly aberrant sediment type (>80% clay) at station CW04 suggest that we may actually have sampled within the channel rather than on the adjacent bank. This was probably a consequence of having been forced off station by the exceptionally strong currents and near gale-force winds which prevailed on that particular sampling date.

Table 2. Hydrographic data collected during benthic and nektonic sampling in the Winyah Bay area, South Carolina.

STATION	DATE	DEPTH (m)	LIGHT PENETRATION (m)	TEMPERATURE (c)	SALINITY ($^{o}/oo$)	DISSOLVED OXYGEN (mg/l)
CW01	29-X-80	9.4	1.6	19.8	35.19	7.42
CW02	29-X-80	5.5	1.4	19.4	34.74	7.31
CW03	29-X-80	6.7	1.4	19.4	34.83	7.24
CW04	29-X-80	7.3	0.4	19.5	32.99	6.77
CW05	29-X-80	13.7	0.4	19.1	33.30	6.73
CW06	30-X-80	4.6	0.4	17.2	25.61	7.01
CW07	30-X-80	7.0	0.4	17.4	24.85	6.91
CW08	30-X-80	6.7	0.4	16.1	16.90	7.31
CW09	29-X-80	7.3	0.3	18.5	32.33	6.77
CW10	30-X-80	4.9	0.4	16.4	17.48	6.91
CW11	29-X-80	8.5	0.4	18.6	27.42	6.77
CW12	30-X-80	4.9	0.5	16.2	14.34	7.38

TABLE 1. Bottom temperature and salinity vaules for trawl areas taken during October 1980 in the Winyah Bay system. Channel locales are in the main portion of the channel as defined by the chart whereas bank locales are adjacent to the main channel.

Reach	Area	Tidal Stage	Bottom Temperature (°C)	Salinity (ppt)
Ocean	Channel	High	19.4	34.83
		Low	19.5	35.06
Ocean	Bank	High	19.4	34.74
		Low	19.6	35.10
South Island	Channel	High	22.2	34.01
		Low	18.3	21.92
South Island	Bank	High	22.3	34.39
		Low	18.2	21.92
Western Channel	Channel	High	21.9	32.02
		Low	20.8	12.70
Western Channel	Bank	High	21.0	32.13
		Low	20.5	13.67

RESULTS

I. Hydrography and Sediments

General categories for characterizing estuarine zones on the basis of salinity distribution were established in the Venice System (Symposium on the Classification of Brackish Waters, 1958). These include (1) limnetic (<0.5 $^{o}/oo$); (2) oligohaline (0.5-5 $^{o}/oo$); (3) mesohaline (5-18 $^{o}/oo$); (4) polyhaline (18-30 $^{o}/oo$); and (5) euhaline (30-40 $^{o}/oo$). Application of this scheme to trawl locales occupied in the Winyah Bay system during October 1980 showed that the Ocean Reach area was in the euhaline zone during both high and low tide (Table 1). The South Island Reach experienced a difference of 12^{o}/oo between high and low tide whereas the Western Channel Reach had a 19^{o}/oo range between tidal stages. Thus, we consider both the South Island and Western Channel reaches to have been stressed areas during the October sampling period due to the marked fluctuations in salinity over a tidal cycle. The Ocean Reach was not significantly influenced by salinity changes during the sampling period.

Salinities of bottom water samples taken at each of the benthic sampling sites ranged from a low of 14.34^{o}/oo at Western Channel station CW12 to a high of 35.19^{o}/oo at off-shore station CW01 (Table 2). Euhaline salinities were recorded at all stations in the ocean reach of the sampling area (CW01 through CW05) and at station CW09. Salinities were in the polyhaline range at stations CW06, CW07 and CW11, while mesohaline salinities were recorded at Western Channel stations CW08, CW10 and CW12. Salinities at channel stations CW09 and CW11 were unexpectedly high since these stations were located in the same reach of the bay as stations CW08, CW10 and CW12. Considering the wide fluctuations in salinity between high and low tides, however, this apparent descrepancy is probably the result of having sampled logarithmic transformed data; the sorting strategy was flexible with $\beta = -0.25$ (Clifford and Stephenson, 1975). Nodal analysis was subsequently used to detect misclassifications and to determine the suitability of species and site groups. Species/site group coincidences were interpreted in terms of constancy and fidelity (see p.11).

In addition to the nodal analysis, the percent occurrence for each species was calculated for each site group and its mean catch/tow was calculated on ln (number + 1) transformed data. The Bliss approximation was applied to the logarithmic values to obtain arithmetic values according to the following expression:

$$E\,\bar{x} = \{\mathrm{Exp}\,(\bar{x}_i + \frac{s_i^2}{2})\} - 1$$

Where $E\,\bar{x}$ = estimated mean (Bliss, 1967) in arithmetic units

$\bar{x}_i$ = mean catch/tow for i^{th} site group in logarithmic units

s_i^2 = variance of the mean catch/tow of a species in the i^{th} site group in logarithmic units squids) and weighed to the nearest gram on an Ohaus Dial-O-Gram scale.

Catch/effort for dominant fish and decapod species was calculated for high and low tides at each sampling site by the index of relative abundance (Musick and McEachran, 1972).

$$IA = \frac{1}{n} \Sigma \ln (x + 1)$$

Where IA = index of abundance

n = number of tows at a given site (n = 3)

x = number or weight of a given species for each tow at a site.

The area swept by the eight minute trawl tows in hectares (estimated distance = 617.1 m) was calculated (Klima, 1976) by the expression:

$$a = \frac{k \times m \times 0.6\ (H)}{10{,}000\ m^2/\text{hectare}}$$

Where a = area in ha

k = vessel speed in m/hr

m = hours fished

H = headrope length in m

Each of the thirty-six trawl tows sampled an estimated 0.293 ha. This was used to obtain the density of the total fish and decapod catch at each site.

Species diversity, richness and evenness were measured on trawl caught fishes, decapods and squids using the same indices described in the benthic ecology section (see p. 8).

Clustering techniques were utilized to compare the similarity between assemblages of organisms (normal analysis) and to compare the similarity in the distribution patterns of species (inverse analysis) (Boesch, 1977). Species encountered in only a single collection were not included in the analysis. The Bray-Curtis similarity coefficient (see p.10) was used on

Nodal constancy is a measure of how consistently the members of a particular species group occur among the stations of a given site group. It is expressed as:

$$C_{ij} = a_{ij}/(n_i n_j)$$

where, C_{ij} is the constancy of species group i in collection group j; a_{ij} is the actual number of individuals of species group i in collection group j; and, n_i and n_j are the numbers of entities in groups i and j, respectively.

Nodal fidelity is a measure of the degree to which a given species group is restricted to a particular site group. This index is expressed as:

$$F_{ij} = (a_{ij}\sum_j n_j)/n_j\sum_j a_{ij})$$

where, F_{ij} is the faithfulness of species group i to collection group j and the other notation is the same as above.

II. Trawl-Caught Fishes and Decapod Crustaceans

At each of six designated trawl areas (Fig. 1), three eight minute trawl tows were made at both high and low tides from the R/V Anita, a 16 m vessel equipped for stern trawling, at a speed of 2.5 knots (4.6 km/hr). The net was a 1.25 inch (3.18 cm) stretch mesh 30 foot (9.14 m) footrope, 26 foot (7.92 m) head rope four seam semi-balloon shrimp trawl. It was fished with 150 foot (47.5 m) bridles attached to wooden chain doors from a single trawl warp. Two eight inch (20.3 cm) floats were lashed to the headrope midway between the door and adjusted so that it was dragged approximately 18 inches (45 cm) in front of the net. Bottom temperatures were recorded and salinity samples were taken after the three replicate trawl tows in each of the study areas following both high and low tides.

Fishes, decapod crustaceans and squids were sorted, identified to the lowest possible taxon (in all but two instances to species), counted, measured to the nearest mm (total or fork length for teleosts; disc width for batoid elasmobranchs; total or long carapace width for decapods; mantle length for whose sporadic occurrence in large numbers seemed to merit their inclusion in subsequent analyses. The raw species scores were then subjected to a logarithmic transformation in order to reduce the importance of the more abundant species relative to the less abundant ones whose contribution to the faunal character of an assemblage would otherwise have been overwhelmed.

Similarities between pairs of entities (either species or sites) were measured using the Bray-Curtis (1957) similarity coefficient. It is given by the formula:

$$S_{jk} = \frac{2\sum_i \min(X_{ij}, X_{ik})}{\sum_i (X_{ij}+X_{ik})} \quad \text{(Clifford and Stephenson, 1975)}$$

where, S_{jk} is the similarity between entities j and k; X_{ij} is the value of the i^{th} attribute for entity j; and X_{ik} is the comparable value for entity k. In a normal analysis the entities are sites and the attributes are the transformed species abundance scores; whereas, in an inverse analysis the entities are species and the attributes are the sites at which they occur.

The clustering algorithm chosen was the space-dilating flexible sorting strategy developed by Lance and and Williams (1967). Moderately intense clustering was effected by setting the cluster-intensity coefficient, β, at the now standard value, -0.25. While this technique is generally prone to misclassification and is group-size dependent, it is thought to produce classifications having the greatest ecological sense (Boesch, 1977).

Finally, nodal analyses were used to assist in the reallocation of entities by identifying misclassifications. More importantly, however, they aided in the ecological interpretation of the normal and inverse classifications by expressing the degree of species/site group coincidences in terms of the classic community concepts of constancy and fidelity.

by:

$$H' = -\sum_{i=1}^{S} P_i \log_2 P_i$$

where, S = the number of species in a given sample

P_i = the proportion of individuals belonging to the i^{th} species in that sample

The two components of species diversity are species richness and species evenness. Species richness is expressed as a logarithmic relationship between the number of species (S) and the number of individuals (N) in the sample:

$$SR = (S-1)/\ln N \text{ (Margalef, 1968)}$$

Species evenness is inversely related to numerical dominance and, as such, provides an indirect measure of this community parameter. It is expressed as follows:

$$J' = H'/H'max \text{ (Pielou, 1975)}$$

where, H' = the species diversity of a sample in bits/individual

$H'max = \log_2 S$

Numerical classification, or cluster analysis, was used in order to group stations on the basis of their similarity with respect to the faunal assemblages found at each. This application of clustering is known as a _normal analysis_. Similarly, species were grouped on the basis of their similarity with respect to their patterns of distribution and abundance among the sampling sites. This is known as an _inverse analysis_.

Prior to calculating inter-entity similarities, the data set was edited by eliminating all those species occurring at only one site _and_ having a total abundance amounting to less than 0.1% of the total number of individuals for all species at the site where it occurred. This procedure effectively reduced the size of the data set from 154 to 83 species while preserving those rare species

Bottom water samples were collected using a Van Dorn bottle at each of the 12 sites designated for benthic sampling. Parameters measured included temperature, salinity, and dissolved oxygen. Water temperatures were measured in the field by stem thermometers mounted inside the Van Dorn bottle. All other samples were returned to the laboratory for subsequent chemical analysis. Salinity samples were analyzed using a Beckman Model RS7B Induction Salinometer. Dissolved oxygen was determined by the modified Winkler titration method (Strickland and Parsons, 1972).

Sediment samples were taken from one of the three replicate Van Veen grab samples collected at each benthic sampling site. These were analyzed in the laboratory for percent sand, silt, and clay, as well as carbonate content and sand particle size distribution. Silts and clays were separated from sand-size material by wet sieving or washing through a 62 μm screen. Silt was separated from clay by pipette analysis following the procedure described in Folk (1974). Calcium carbonate shell was separated from quartz sand-size material by HCl digestion. Quartz sand-size fractions were further separated by settling tube analysis following a modification of the procedure described in Zeigler et al. (1960).

After identification and enumeration of the fauna from quantitative grab samples, diversity was measured by the commonly used Shannon-Weaver index (Pielcu, 1975) which is an expression of the average information content per individual. The index denotes the degree of uncertainty in predicting the specific identity of an individual selected at random from a multi-species assemblage. This uncertainty is a function of the population proportions of the several species in a sample. The more species there are and the more equally they are represented, the higher the diversity. The formula is given

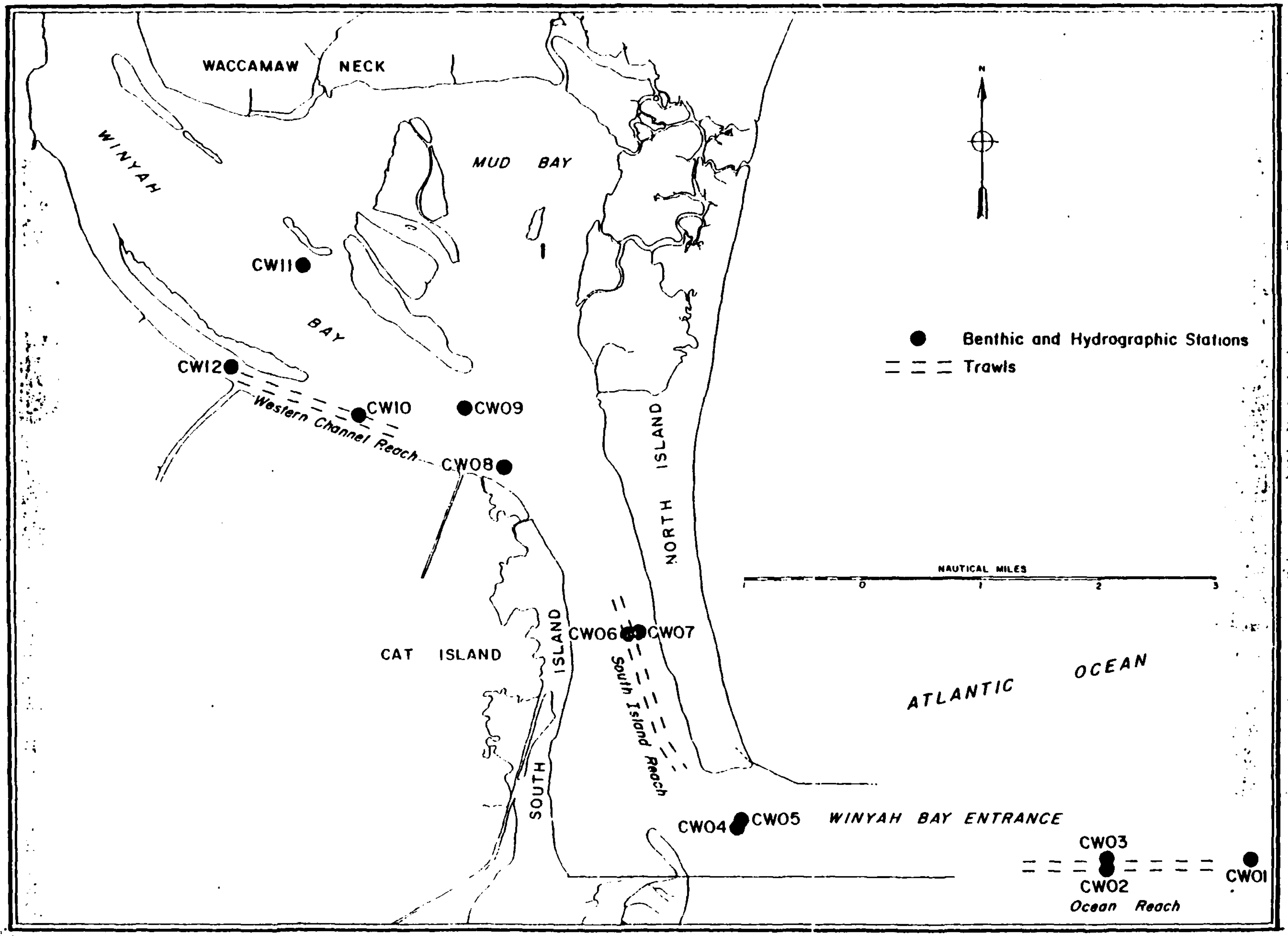

WACCAMAW NECK
WINYAH
MUD BAY
BAY
CW11
CW12
CW10
CW09
CW08
Western Channel Reach
Benthic and Hydrographic Stations
Trawls
N
NORTH ISLAND
NAUTICAL MILES
1 0 1 2 3
CAT ISLAND
SOUTH ISLAND
CW06
CW07
South Island Reach
ATLANTIC OCEAN
CW04
CW05
WINYAH BAY ENTRANCE
CW03
CW02
CW01
Ocean Reach

Figure 1. Location map for each of 12 benthic stations and 6 trawl areas established in three reaches of the Winyah Bay system and sampled in October, 1980.

MATERIALS AND METHODS

I. Benthic Ecology

Benthic sampling was undertaken during October 1980 at 12 stations in and around lower Winyah Bay and the Winyah Bay entrance channel (Figure 1). One station (CW01) was located at the oceanward extent of the proposed dredging project near the 37-foot contour. Five stations (CW03, CW05, CW07, CW09, and CW11) were located within the existing channel to Georgetown, while three others (CW02, CW04, and CW06) were located on the banks immediately adjacent to the channel. Finally, three stations (CW08, CW10 and CW12) were sited in the proposed Western Channel turning basin.

Three replicate quantitative samples were collected at each station using a 0.10 m^2 Van Veen grab. Each sample was immediately washed through a 0.5 mm sieve. Organisms and sediment remaining on the sieve after washing were removed to appropriately labelled gallon jugs or bottles and preserved in a 10% seawater-formaldehyde solution containing the vital stain rose bengal. Collections were returned to the laboratory for sorting, identification, and enumeration of the fauna.

Quantitative samples were supplemented with qualitative collections taken with a 30 kg modified oyster dredge. The dredge consisted of a rectangular steel frame measuring 80 cm across the mouth, with a 1.5 m-long bag of 2.5 cm stretch mesh polypropylene. A skirt of interlacing metal rings protected the bag from chafing. A single tow of three minutes at approximately three knots was made at each of the 12 stations. After preliminary sorting of the catch in the field, unidentified invertebrates and a representative sample of firm substrates were preserved in 10% formalin and returned to the laboratory for examination and identification.

The results of a reconnaisance study of Winyah Bay's hydrography (Johnson, 1970) showed that dissolved oxygen concentrations during the winter months ranged from 8.5 to 11.8 mg/l with an average of 10.0 mg/l. This represents a saturation level of 75-95%. Water temperatures ranged from 6^{o}C in the winter to 30.0^{o}C in the summer. Chemical analyses indicated that freshwater inflow to Winyah Bay is of a quality suitable for most agricultural, industrial and domestic uses. The waters of Winyah Bay itself, however, have been designated "Class SC" by the South Carolina Department of Health and Environmental Control. This is the lowest water quality classification for saline waters in the state. Such waters are deemed suitable for crabbing, commercial fishing or other uses (except bathing and shellfishing for market purposes), and for uses requiring water of lesser quality. This classification applies to waters extending from the Winyah Bay entrance to the U. S. Highway 17 bridge on the Waccamaw River arm, and in the Pee Dee arm to the mouth of the Black River. The bed sediments of Winyah Bay are relatively unpolluted by pesticides, but show some evidence of contamination by trace metals.

Table 3. Percent composition and Shepard's classification of sediments taken from benthic grab samples collected at each of 12 sites in the Winyah Bay area.

Station	% $CaCO_3$	% Sand (-1-4Ø)	% Silt (4-8Ø)	% Clay (8-12Ø)	Shepard's Classification
CW01	7.6	92.4	0.0	0.0	Sand
CW02	4.5	95.5	0.0	0.0	Sand
CW03	5.1	1.6	22.4	70.9	Silty-Clay
CW04	1.0	7.7	11.2	80.1	Clay
CW05	2.6	97.4	0.0	0.0	Sand
CW06	1.0	99.0	0.0	0.0	Sand
CW07	25.2	74.8	0.0	0.0	Sand
CW08	8.7	7.1	9.8	74.4	Sandy-Clay
CW09	1.0	63.3	1.7	34.0	Clayey-Sand
CW10	0.0	6.3	9.1	84.6	Clay
CW11	0.0	63.3	1.3	35.4	Clayey-Sand
CW12	0.0	0.0	2.7	97.3	Clay

Channel stations in the upper reach of the sampling area (CW09 and CW11) had clayey-sand sediments, while stations along the proposed Western Channel turning basin had sediments composed of sandy-clay (CW08) or clay (CW10 and CW12).

Thus, with respect to sediment type, dredging operations appear to have had different effects in the ocean reach than they have had in the lower and middle reaches of Winyah Bay. Off-shore dredging seems to have decreased current velocities within the channel sufficiently to have changed a physically dynamic bottom into a relatively quiescent, depositional one. This, in turn, has resulted in increased sedimentation and an alteration of sediment type from sand to silty-clay at stations CW03 and CW04. On the other hand, dredging within the bay itself has resulted in the removal of large quantities of alluvial silt and clay, exposing an underlying layer of sand at some sites. Similar effects have been documented by other researchers (Kaplan et al., 1975).

Finally, the percent composition of the coarse fractions alone, indicate that sediments from all stations having a sand component exhibit a bimodal or polymodal distribution of particle sizes with the highest frequencies generally occurring in the fine, medium and coarse sand categories (Table 4).

Table 4. Percent composition of the coarse fraction alone.

Station	% Gravel (<-1Ø)	% Very Coarse Sand (-1-1Ø)	% Coarse Sand (0-1Ø)	% Medium Sand (1-2Ø)	% Fine Sand (2-3Ø)	% Very Fine Sand (3-4Ø)
CW01	1.2	0.0	40.0	47.3	10.4	0.7
CW02	1.0	0.0	32.2	56.5	9.3	1.1
CW03*	-	-	-	-	-	-
CW04	1.1	0.0	1.7	30.3	49.8	17.1
CW05	0.9	0.0	26.9	63.4	8.2	0.4
CW06	0.8	0.0	11.5	45.6	40.7	1.4
CW07	0.7	1.6	64.9	18.0	14.1	0.8
CW08	0.9	1.5	12.0	22.0	50.9	13.3
CW09	1.8	0.0	21.9	46.1	27.2	3.4
CW10	2.6	0.0	3.0	17.7	32.5	45.0
CW11	1.8	0.0	4.8	44.5	46.1	3.2
CW12	0.0	0.0	0.0	0.0	0.0	0.0

*Sample too small for analysis

II. Trawl-Caught Fishes and Decapod Crustaceans

Species Diversity

Species diversity of trawl caught fishes, decapods and squids was highest in the Ocean Reach site and lower in Winyah Bay proper (Table 5). This was due to high values of both evenness and species richness at this site in comparison to the Western Channel and South Island reaches (Table 5). Tidal differences were only apparent in high tide tows in the channel of the South Island Reach where diversity values were lower than in tows made during low tide in the same area.

The total number of decapod and fish species, in addition to the mean number of species/tow, was highest in the Ocean Reach area and lower inside Winyah Bay (Table 6). These values essentially paralleled the index values of diversity, evenness and richness.

Cluster and Nodal Analysis

Numerical classification of otter trawl tows gave four site groups (Fig. 2). Group 1 was composed of twelve trawl tows made during high and low tide in both the channel and adjacent to the channel (bank) in the Western Channel Reach. Within this site group there was a suggestion of tidal differences in trawl collections, however, they were so highly similar to each other in faunal composition that further splitting seemed unwarranted. Group 2 included four tows from the South Island Reach while the remainder of tows from that reach comprised site group 3. Finally, group 4 contained all samples taken in the Ocean Reach.

Incidental observations on the substrate catch in the trawl nets at each location showed that all tows in the Western Channel Reach were made on mud bottom. The net contained decomposing plant remains and small amounts of mud,

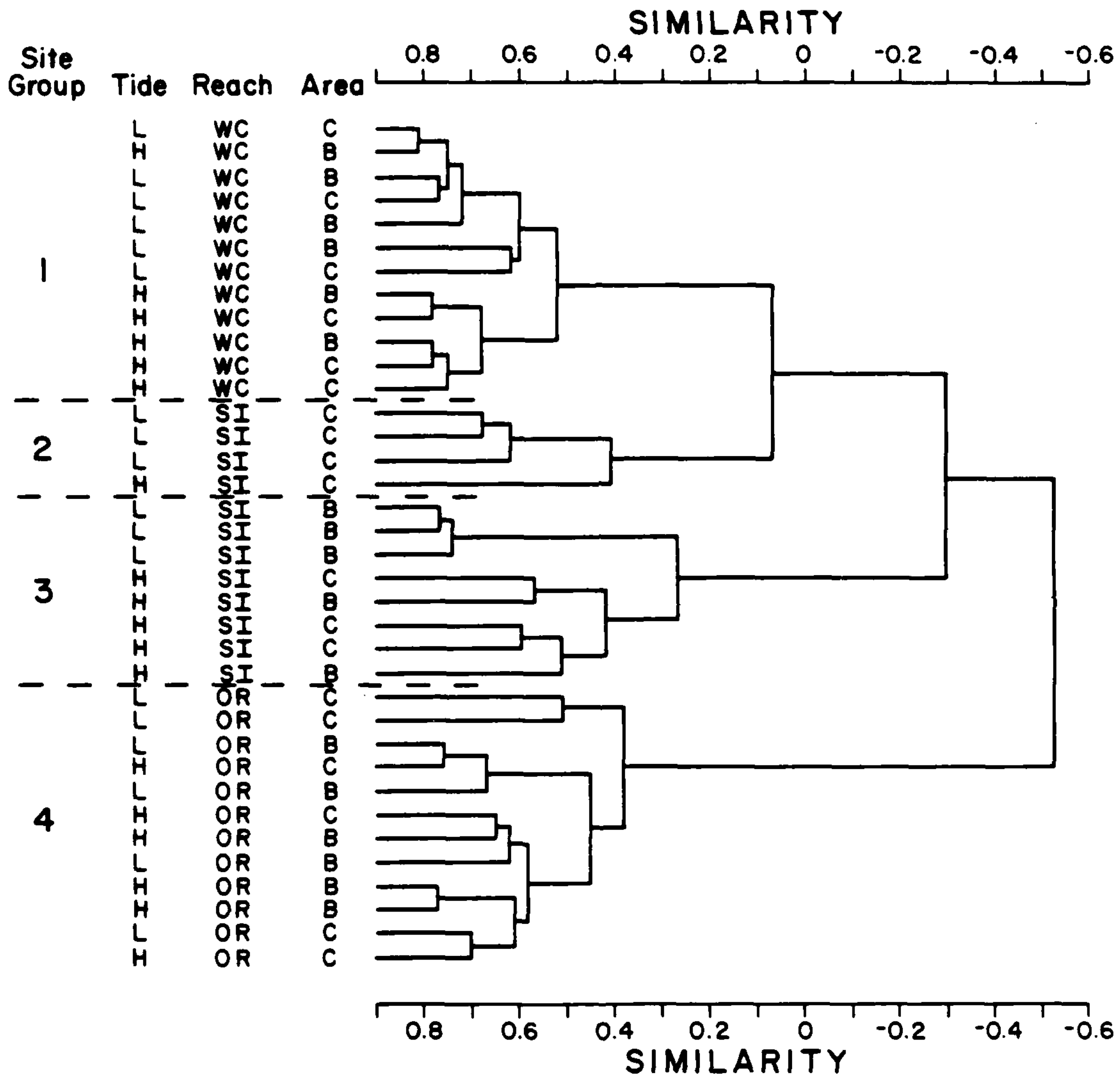
TABLE 5. Diversity statistics for otter trawl tows during October 1980 in Winyah Bay. Species include fishes, decapod crustaceans and squids.

Location		Tide	Replicate Number	Number of Species	Number of Individuals	(Bits/Ind.)	Evenness	Richness ($s^{-1}/\ln N$)
Western Channel Reach	Bank	Low	1	12	383	1.820	0.507	1.849
			2	10	315	1.823	0.548	1.564
			3	16	350	2.048	0.512	2.560
Western Channel Reach	Channel	Low	1	14	280	2.251	0.591	2.307
			2	14	291	2.298	0.603	2.291
			3	16	544	1.948	0.487	2.381
Western Channel Reach	Bank	High	1	10	88	2.705	0.814	2.010
			2	13	257	2.079	0.561	2.162
			3	16	140	2.699	0.674	3.035
Western Channel Reach	Channel	High	1	13	122	2.659	0.718	2.497
			2	17	154	3.102	0.759	3.176
			3	13	82	2.984	0.806	2.723
South Island Reach	Bank	Low	1	16	257	2.904	0.726	2.703
			2	18	210	3.234	0.775	3.179
			3	17	164	3.073	0.751	3.137
South Island Reach	Channel	Low	1	11	72	2.336	0.675	2.338
			2	10	105	1.860	0.560	1.933
			3	7	97	1.673	0.596	1.311
South Island Reach	Bank	High	1	14	149	1.669	0.438	2.597
			2	16	45	3.096	0.774	3.940
			3	14	157	2.452	0.644	2.571
South Island Reach	Channel	High	1	8	51	1.887	0.629	1.780
			2	9	32	2.510	0.791	2.308
			3	8	52	2.562	0.854	1.771
Ocean Reach	Bank	Low	1	26	569	2.802	0.596	3.940
			2	19	223	2.665	0.627	3.328
			3	17	99	2.814	0.688	3.482
Ocean Reach	Channel	Low	1	16	87	2.887	0.721	3.358
			2	19	295	2.158	0.508	3.165
			3	15	95	2.630	0.673	3.074
Ocean Reach	Bank		1	18	233	2.497	0.599	3.118
			2	17	170	3.322	0.812	3.115
			3	26	98	3.810	0.810	5.452
Ocean Reach	Channel		1	18	142	3.174	0.761	3.430
			2	26	411	2.741	0.583	4.153
			3	18	61	3.623	0.868	4.135

TABLE 6. Values for total species, fish, decapod and squid species taken in trawl tows in Winyah Bay during October 1980 by reach, area and tidal stage.

Reach	Area	Tide	Species Fish	Decapods	Squid	Total	Mean No. Species/tow
Western Channel	Bank	Low	12	8	--	20	12.7
		High	13	6	--	19	13.0
Western Channel	Channel	Low	16	7	--	23	14.7
		High	14	5	--	19	14.3
South Island	Bank	Low	14	10	--	24	17.0
		High	11	12	--	23	14.7
South Island	Channel	Low	12	6	--	18	9.3
		High	5	8	1	14	8.3
Ocean	Bank	Low	19	14	1	34	20.7
		High	20	14	1	35	20.3
Ocean	Channel	Low	15	16	--	31	16.7
		High	17	15	1	33	20.7

Figure 2. Site groups generated by a normal cluster analysis of channel and bank trawls made at high and low tides in each of three reaches of the Winyah Bay system.



TIDE L=LOW
H=HIGH

REACH WC=WESTERN CHANNEL
SI=SOUTH ISLAND
O =OCEAN

AREA C=CHANNEL
B=BANK

organic debris and a few empty oyster shells. The other eight tow in the South Island Reach (group 3) had large amounts of oyster shells and/or chunks of Cooper marl (a sedimentary rock associated with the Cooper formation).

The main classificatory separation was between coastal, high salinity stations (Ocean Reach) and trawl tows made in the Winyah Bay system. The lower, less stable salinity regime of the Western Channel Reach with its relatively homogeneous,muddy bottom type formed a cohesive site group. The mid-bay station (South Island Reach) was subdivided into the mud (site group 2) and hard bottom (oyster shell, marl rock) site groups (group 3). Thus, both salinity and substrate type affect the faunal composition of trawl-caught organisms at a given site.

Inverse analysis (species cluster) gave seven groups (Fig. 3), each containing from five to thirteen species. As with the normal analysis, the major break in the classification came between coastal high salinity organisms and estuarine forms. The percent occurrence for members of each species group as well as their mean catch/tow values within each site group are reported in Table 7.

Species group A was composed of three species of decapods and seven species of fishes that occurred in trawl tows from all site groups. The high constancy values (Fig. 4) in conjunction with low fidelity values (Fig. 5) indicated that this species assemblage can be expected to comprise a major component of the trawl-caught fauna within the bounds of the study area during this season. Group B,with five species,contained organisms that were not very abundant but did occur more frequently in site group 1 (Western Channel Reach) than at other sites (Table 7). Group C had moderate fidelity and very high constancy to site group 3. Although members of this group occurred at all sites, their greatest frequency of occurrence and catch/tow values were in site group 3

Figure 3. Species groups generated by an inverse cluster analysis of trawl-caught fishes and decapod crustaceans from the Winyah Bay system.

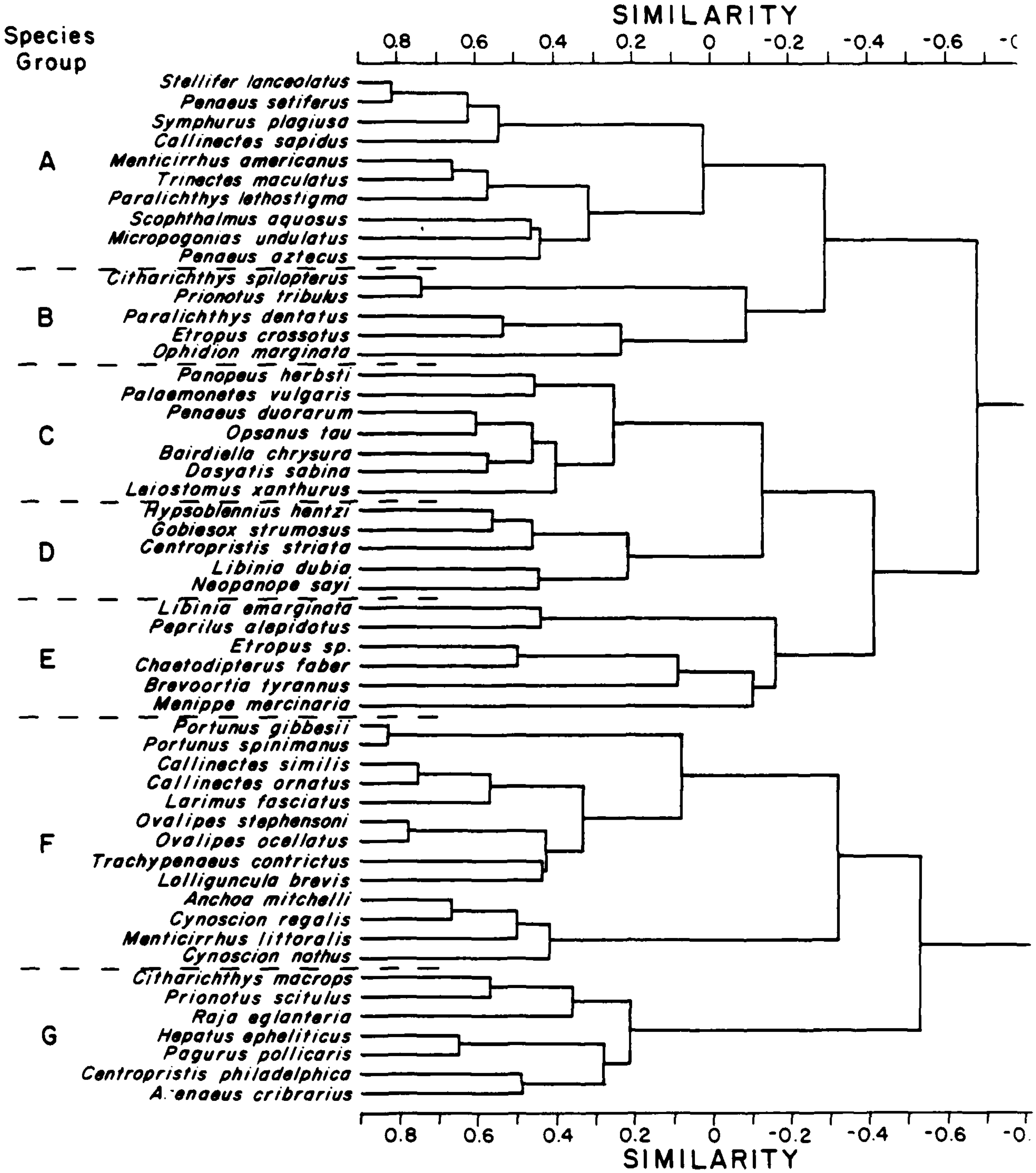

SIMILARITY
Species Group
0.8 0.6 0.4 0.2 0 -0.2 -0.4 -0.6
A
Stellifer lanceolatus
Penaeus setiferus
Symphurus plagiusa
Callinectes sapidus
Menticirrhus americanus
Trinectes maculatus
Paralichthys lethostigma
Scophthalmus aquosus
Micropogonias undulatus
Penaeus aztecus
B
Citharichthys spilopterus
Prionotus tribulus
Paralichthys dentatus
Etropus crossotus
Ophidion marginata
C
Panopeus herbsti
Palaemonetes vulgaris
Penaeus duorarum
Opsanus tau
Bairdiella chrysura
Dasyatis sabina
Leiostomus xanthurus
D
Hypsoblennius hentzi
Gobiesox strumosus
Centropristis striata
Libinia dubia
Neopanope sayi
E
Libinia emarginata
Peprilus alepidotus
Etropus sp.
Chaetodipterus faber
Brevoortia tyrannus
Menippe mercinaria
F
Portunus gibbesii
Portunus spinimanus
Callinectes similis
Callinectes ornatus
Larimus fasciatus
Ovalipes stephensoni
Ovalipes ocellatus
Trachypenaeus contrictus
Lolliguncula brevis
Anchoa mitchelli
Cynoscion regalis
Menticirrhus littoralis
Cynoscion nothus
G
Citharichthys macrops
Prionotus scitulus
Raja eglanteria
Hepatus epheliticus
Pagurus pollicaris
Centropristis philadelphica
Arenaeus cribrarius
0.8 0.6 0.4 0.2 0 -0.2 -0.4 -0.6
SIMILARITY

Figure 4. Cluster dendrograms and nodal constancy table for trawl-caught fishes and decapod crustaceans from the Winyah Bay system.

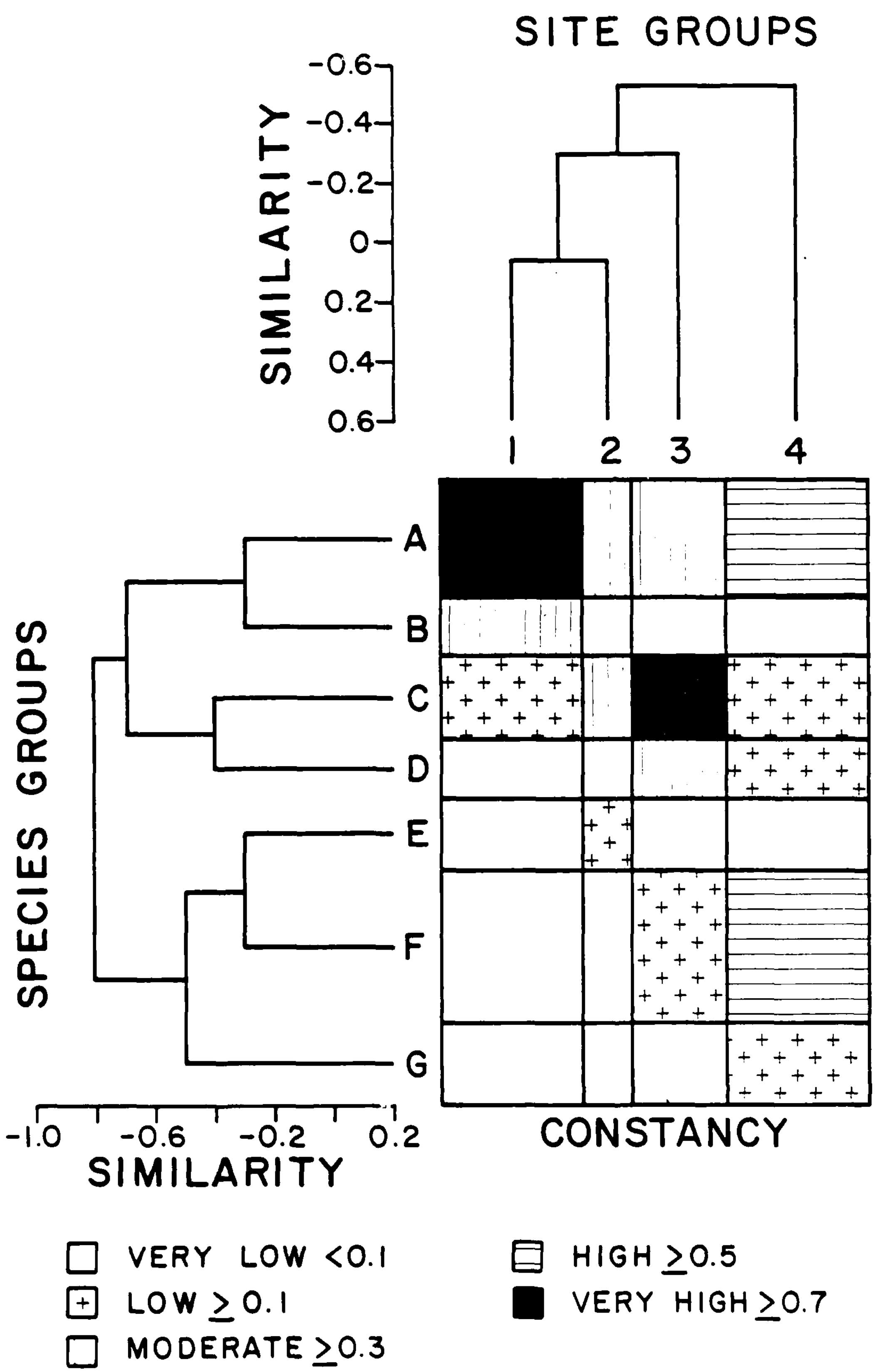
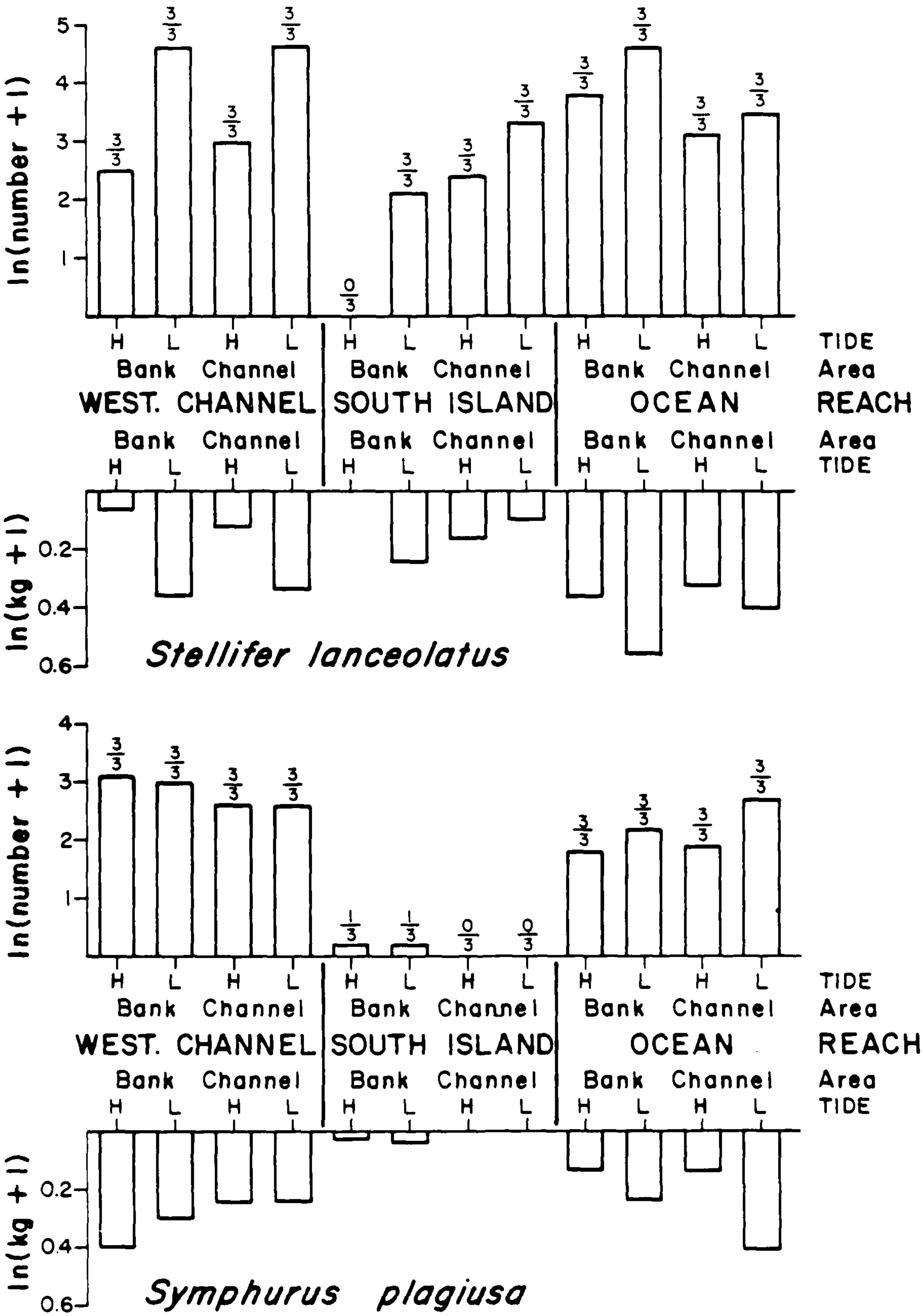

SITE GROUPS
SIMILARITY
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
1
2
3
4
SPECIES GROUPS
A
B
C
D
E
F
G
-1.0
-0.6
-0.2
0.2
SIMILARITY
CONSTANCY
VERY LOW <0.1
LOW ≥ 0.1
MODERATE ≥0.3
HIGH ≥0.5
VERY HIGH ≥0.7

Figure 5. Cluster dendrograms and nodal fidelity table for trawl-caught fishes and decapod crustaceans from the Winyah Bay system.

Figure 7. Length frequency distribution for stardrum, *Stellifer lanceolatus*, collected from the Winyah Bay system during October, 1980.



ln(number + 1)
ln(kg + 1)
TIDE
Area
REACH
Bank
Channel
WEST. CHANNEL
SOUTH ISLAND
OCEAN
Stellifer lanceolatus
Symphurus plagiusa

Figure 6. Index of relative abundance for stardrum, Stellifer lanceolatus (A), and blackcheek tonguefish, Symphurus plagiusa (B), collected from the Winyah Bay system during October, 1980. Numerator in fraction above ln(number +1) = number of occurrences at sampling site; denominator = number of trawl tows at site. H = high tide; L = low tide. Bank = results from trawl tows made in the area adjacent to the charted position of the channel; Channel = results from trawl tows made in the charted position of the channel. See Figure 1 for location of reaches.

TABLE 13. Ranking by weight of fishes taken during thirty-six trawl tows in the Winyah Bay system during October, 1980.

Species	Total Weight (kg)	Percent of Catch	Cumulative Percent
Opsanus tau	51.131	38.39	
Dasyatis sabina	30.153	22.64	61.03
Leiostomus xanthurus	13.041	9.79	70.82
Stellifer lanceolatus	11.596	8.71	79.53
Symphurus plagiusa	7.882	5.92	85.45
Paralichthys lethostigma	3.693	2.77	88.22
Micropogonias undulatus	3.124	2.34	90.56
Raja eglanteria	2.539	1.91	92.47
Menticirrhus americanus	1.947	1.46	93.93
Brevoortia tyrannus	1.562	1.17	95.10
Bairdiella chrysura	1.249	0.94	96.04
Trinectes maculatus	0.980	0.74	96.78
Menticirrhus littoralis	0.662	0.50	97.28
Centropristis philadelphica	0.578	0.43	97.71
Scophthalmus aquosus	0.539	0.40	98.11
Paralichthys dentatus	0.530	0.40	98.51
Etropus crossotus	0.278	0.21	98.72
Conger oceanicus	0.233	0.17	98.89
Ophidion marginata	0.232	0.17	99.06
Cynoscion regalis	0.200	0.15	99.21
Prionotus tribulus	0.129	0.10	99.31
Centropristis striata	0.114	0.09	99.40
Peprilus alepidotus	0.114	0.09	99.49
Citharichthys spilopterus	0.085	0.06	99.55
Sphoeroides maculatus	0.082	0.06	99.61
Larimus fasciatus	0.076	0.06	99.67
Hypsoblennius hentzi	0.064	0.05	99.72
Citharichthys macrops	0.062	0.05	99.77
Gobiesox strumosus	0.059	0.04	99.81
Archosargus probatocephalus	0.043	0.03	99.84
Chaetodipterus faber	0.038	0.03	99.87
Etropus sp.	0.035	0.03	99.90
Anchoa mitchilli	0.033	0.02	99.92
Cynoscion nothus	0.031	0.02	99.94
Anchoa hepsetus	0.021	0.02	99.96
Prionotus scitulus	0.014	0.01	99.97
Chloroscombrus chysurus	0.009	-----	-----
Prionotus salmonicolor	0.007	-----	-----
Ogcocephalus rostellum	0.005	-----	-----
Stephanolepis hispidus	0.005	-----	-----
Selene setapinnis	0.001	-----	-----

blackcheek tonguefish, S. plagiusa accounted for 85.45% of the total weight of fishes taken during the survey (Table 13).

Stardrum: Stellifer lanceolatus

Stellifer lanceolatus ranked first in numerical abundance and forth by weight of the fish catch during the survey. It was collected in 33 of 36 trawl tows (Fig. 6A) and showed its maximum catches during low tide in the Western Channel Reach. It was absent in the 3 tows made in the South Island Reach adjacent to the main channel during high tide. Length frequency distributions (Fig. 7) showed that a greater number of larger fish were collected in the higher salinity Ocean Reach than inside Winyah Bay proper. Stardrum taken in the Western Channel Reach average 70 mm total length whereas those from the South Island and Ocean reaches averaged 86 and 92 mm total length respectively. Although both large and small individuals were found throughout the study area, a greater percentage of the fish taken in the higher salinity portions were larger. This could indicate that as S. lanceolatus increase in size they move into the higher salinity coastal waters from the estuarine nursery grounds.

Blackcheek tonguefish: Symphurus plagiusa

Symphurus plagiusa was the second most numerically abundant fish species comprising 12.69% of the fish catch. Catches were highest in the Western Channel and Ocean reaches where it was encountered in all trawl tows. Greatest numbers of S. plagiusa were taken at bank stations in the Western Channel Reach and at low tide stations in the Ocean Reach (Fig. 6B). It was taken in only two of the twelve trawl tows made in the South Island Reach and was represented by only two specimens. Size of S. plagiusa increased slightly

TABLE 12. Numerical ranking of fish species taken in thirty-six trawl tows in the Winyah Bay System during October, 1980.

Species	Total Number	Percent of Catch	Cumulative Percent
Stellifer lanceolatus	1,696	60.81	
Symphurus plagiusa	345	12.37	73.18
Opsanus tau	171	6.13	79.31
Menticirrhus americanus	84	3.01	82.32
Leiostomus xanthurus	74	2.65	84.97
Micropogonias undulatus	67	2.40	87.37
Trinectes maculatus	58	2.08	89.45
Dasyatis sabina	41	1.47	90.92
Paralichthys lethostigma	35	1.25	92.17
Bairdiella chrysura	34	1.22	93.39
Brevoortia tyrannus	25	0.89	94.28
Etropus crossotus	17	0.61	94.89
Scophthalmus aquosus	17	0.61	95.50
Cynoscion regalis	15	0.54	96.04
Larimus fasciatus	11	0.39	96.43
Cynoscion nothus	9	0.32	96.75
Ophidion marginata	9	0.32	97.07
Anchoa mitchilli	8	0.29	97.36
Paralichthys dentatus	8	0.29	97.65
Citharichthys spilopterus	6	0.21	97.86
Gobiesox strumosus	6	0.21	98.07
Hypsoblennius hentzi	6	0.21	98.28
Prionotus tribulus	6	0.21	98.49
Centropristis striata	5	0.18	98.67
Raja eglanteria	5	0.18	98.85
Centropristis philadelphica	4	0.14	98.99
Citharichthys macrops	4	0.14	99.13
Menticirrhus littoralis	3	0.11	99.24
Peprilus alepidotus	3	0.11	99.35
Prionotus scitulus	3	0.11	99.46
Anchoa hepsetus	2	0.07	99.53
Chaetodipterus faber	2	0.07	99.60
Etropus sp.	2	0.07	99.67
Archosargus probatocephalus	1	0.04	99.71
Chloroscombrus chrysurus	1	0.04	99.75
Conger oceanicus	1	0.04	99.79
Ogcocephalus rostellum	1	0.04	99.83
Prionotus salmonicolor	1	0.04	99.87
Selene setapinnis	1	0.04	99.91
Sphoeroides maculatus	1	0.04	99.95
Stephanolepis hispidus	1	0.04	99.99

TABLE 11. Families of fishes taken in 36 trawl tows in the Winyah Bay system during October 1980 ranked by weight.

Family	Total Weight (kg)	Percent of Fish Catch	Cumulative Percent
Batrachoididae	51.131	38.39	
Sciaenidae	31.926	23.97	62.36
Dasyatidae	30.153	22.64	85.00
Cynoglossidae	7.882	5.92	90.92
Bothidae	5.222	3.92	94.84
Rajidae	2.539	1.91	96.75
Clupeidae	1.562	1.17	97.92
Soleidae	0.980	0.74	98.66
Serranidae	0.692	0.52	99.18
Congridae	0.233	0.17	99.35
Ophidiidae	0.232	0.17	99.52
Triglidae	0.150	0.11	99.63
Stromateidae	0.114	0.09	99.72
Tetraodontidae	0.082	0.06	99.78
Blenniidae	0.064	0.05	99.83
Gobiesocidae	0.059	0.04	99.87
Engraulidae	0.054	0.04	99.91
Sparidae	0.043	0.03	99.94
Ephippidae	0.038	0.03	99.97
Carangidae	0.009	0.01	99.98
Balistidae	0.005	-----	-----
Ogcocephalidae	0.005	-----	-----
	133.175		

TABLE 10. Families of fishes taken in 36 trawl tows in the Winyah Bay system during October 1980 ranked by numerical abundance.

Family	Total Number	Percent of Fish Catch	Cumulative Percent	Number of Species
Sciaenidae	1993	71.25		9
Cynoglossidae	355	12.69	83.94	1
Batrachoididae	171	6.11	90.05	1
Bothidae	88	3.15	93.20	7
Soleidae	58	2.07	95.27	1
Dasyatidae	41	1.47	96.74	1
Clupeidae	25	0.89	97.63	1
Triglidae	10	0.36	97.99	3
Engraulidae	9	0.32	98.31	2
Ophidiidae	9	0.32	98.63	1
Serranidae	9	0.32	98.95	2
Blenniidae	6	0.21	99.16	1
Gobiesocidae	6	0.21	99.37	1
Rajidae	5	0.18	99.55	1
Stromateidae	3	0.11	99.66	1
Carangidae	2	0.07	99.73	2
Ephippidae	2	0.07	99.80	1
Balistidae	1	0.04	99.84	1
Congridae	1	0.04	99.88	1
Ogcocephalidae	1	0.04	99.92	1
Sparidae	1	0.04	99.96	1
Tetraodontidae	1	0.04	100	1
Total	2797			41

TABLE 9. Density estimates of fishes and decapod crustaceans for trawl sites in the Winyah Bay area during October, 1980. Values are in kilograms/hectare and means of three tows each.

Reach	Area	Tidal Stage	Fish Density (kg/ha)	Decapod Density (kg/ha)
Western Channel	Bank	High	4.837	11.747
		Low	6.529	14.530
	Channel	High	3.676	12.151
		Low	7.265	17.543
South Island	Bank	High	9.370	27.369
		Low	82.131	19.512
	Channel	High	11.244	1.489
		Low	2.517	7.242
Ocean	Bank	High	4.605	5.715
		Low	7.080	5.910
	Channel	High	4.954	5.493
		Low	7.663	2.531

In addition to this, there could have been an upstream component to this tidal movement as the up-estuary salinity was raised during flood tide.

The density of fishes was reasonably consistent for all sampling sites with the exception of trawl tows made during low tide on the South Island Bank (Table 9). Samples taken there had large numbers of spot, Leiostomus xanthurus, and oyster toadfish, Opsanus tau, which contributed significantly to the high value. Decapod density was higher in the Western Channel Reach and the bank area of the South Island Reach. White shrimp, Penaeus setiferus, and blue crabs, Callinectes sapidus, were responsible for high Western Channel Reach values whereas high catch rates of blue crabs comprised most of the South Island Reach bank values.

Fishes

The thirty-six trawl tows in the Winyah Bay system resulted in the collection of 41 species of fishes in twenty-two families. The Sciaenidae had the most species (9) and accounted for 71.2% of the total fish catch by number (Table 10). The five most numerically abundant families (Sciaenidae, Cynoglossidae, Batrachoididae, Bothidae, and Soleidae) comprised greater than 95% of the total number of fishes. The toadfish family (Batrachoididae) with one species (Opsanus tau) ranked first by weight contributing 38.39% to the fish catch. The top five families (Batrachoididae, Sciaenidae, Dasyatidae, Cynoglossidae, Bothidae) made up 94.84% of the total fish weight (Table 11).

Stardrum, Stellifer lanceolatus, was by far the most numerically abundant species (Table 12) and was followed by the blackcheek tonguefish, Symphurus plagiusa, the oyster toadfish, Opsanus tau, southern kingfish, Menticirrhus americanus, and spot, Leiostomus xanthurus. Oyster toadfish, O. tau, Atlantic stingray, Dasyatis sabina, spot, L. xanthurus, stardrum, S. lanceolatus, and

TABLE 8. Catches of fishes, decapod crustacean and squids for all tows made in Winyah Bay during October, 1980.

REACH	AREA	TIDAL STAGE	REPLICATE	Fishes		Decapods		Squids		Total	
				No.	kg	No.	kg	No.	kg	No.	kg
Western Channel	Bank	High	1	38	1.255	50	3.263	--	------	88	4.518
			2	78	1.898	179	5.481	--	------	257	7.379
			3	71	1.099	79	1.582	--	------	150	2.681
		Low	1	142	1.526	263	4.259	--	------	405	5.785
			2	111	0.899	204	5.871	--	------	315	6.770
			3	193	3.313	157	2.642	--	------	350	5.955
	Channel	High	1	53	0.709	69	5.781	--	------	122	6.490
			2	91	1.794	63	1.496	--	------	154	3.290
			3	36	0.728	45	3.314	--	------	81	4.042
		Low	1	149	1.571	131	3.100	--	------	280	4.671
			2	83	2.730	208	7.397	--	------	291	10.127
			3	265	2.085	279	4.924	--	------	544	7.009
South Island	Bank	High	1	21	2.598	128	17.921	--	------	149	20.519
			2	16	0.908	29	2.377	--	------	45	3.285
			3	13	4.731	144	3.760	7	0.56	164	8.547
		Low	1	85	19.539	172	8.226	--	------	257	27.765
			2	107	31.182	103	7.377	--	------	210	38.559
			3	142	21.473	104	1.548	--	------	246	23.021
	Channel	High	1	33	0.212	15	0.117	3	0.020	51	0.349
			2	24	5.200	8	0.057	--	------	32	5.257
			3	26	4.472	26	1.135	--	------	52	5.607
		Low	1	18	1.175	54	4.397	--	------	72	4.397
			2	48	0.357	57	1.846	--	------	105	2.203
			3	40	0.681	57	1.298	--	------	97	1.979
Ocean	Bank	High	1	137	0.984	96	1.434	6	0.016	239	2.434
			2	57	0.726	113	2.112	--	------	170	2.838
			3	37	2.338	59	1.478	2	0.005	98	3.821
		Low	1	209	1.730	359	3.683	1	0.014	569	5.427
			2	156	3.361	67	0.727	--	------	223	4.088
			3	64	1.133	33	0.785	2	0.019	99	1.937
	Channel	High	1	45	1.532	97	1.429	--	------	142	2.961
			2	122	1.908	289	2.656	1	0.002	412	4.566
			3	17	0.915	41	0.744	2	0.005	60	1.664
		Low	1	56	1.903	31	0.367	--	------	87	2.270
			2	62	2.931	232	1.150	1	0.022	295	4.103
			3	69	1.902	26	0.708	--	------	95	2.610

which was made up of South Island trawl tows made over oyster shell or marl rock bottoms. Group D had moderate constancy and fidelity to the same site group as species group C, however, they had a lower frequency of occurrence and were less abundant than group C (Table 7). Group E was also comprised of less abundant and less frequently encountered organisms whose affinities for various site groups within the study area were not readily apparent. Species groups F and G were the coastal, higher salinity species. Group G had moderate constancy and high fidelity to Ocean Reach samples. Individual species from this group had their maximum frequency of occurrence and catch/tow values in the Ocean Reach site group (Table 7). Group G consisted of coastal forms with low abundances and frequencies of occurrence.

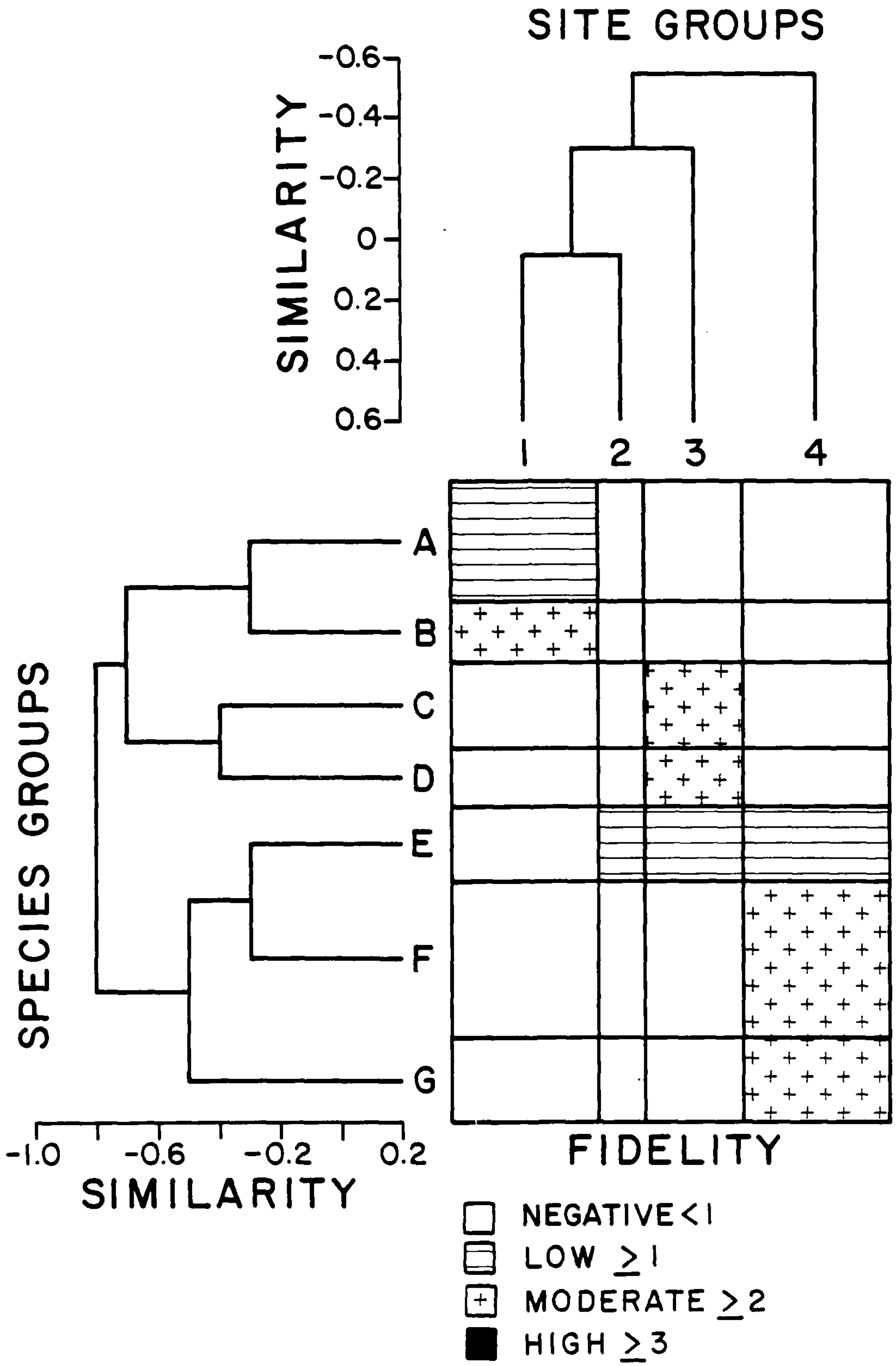
Density

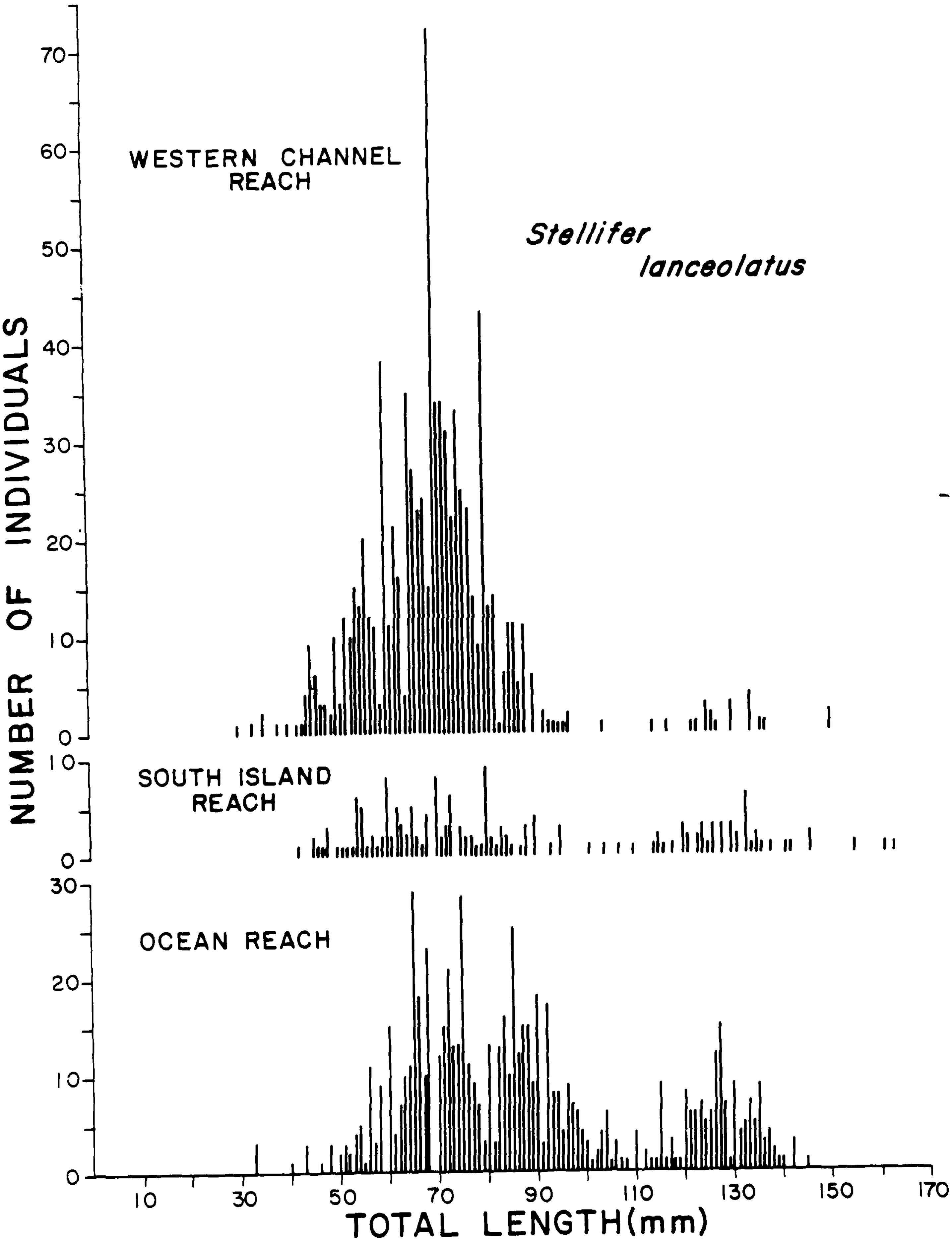
Trawl tows made at low tide in the Western Channel Reach captured more fishes and decapod crustaceans than tows made in the same area at high tide (Table 8). The same pattern was observed in the South Island Reach on the bank adjacent to the channel. Many more individuals with a greater cumulative weight were taken during low tide in this area. Neither trawl tows made in the South Island Reach channel nor those made in the Ocean Reach showed any tidal differences.

The tidal differences at these trawl sites could possibly be explained by their proximity to marsh areas. In the Western Channel Reach, extensive marshes were adjacent to the sampling site. O[illegible]od tides, juveniles of some species, for example <u>Penaeus setiferus</u>, move from channel areas into marshes for food and/or protection. Although the marshes adjacent to the South Island Bank site are not as extensive as those of upstream areas, there could have been some movement of fishes and decapods into the shoal areas during flood tide.

TABLE 7. Percent occurrence and mean catch/tow values for species in the four site groups as defined by cluster analysis. Mean catches are retransformed ln(x + 1) values to which the Bliss (1967) approximation has been applied.

Site Group		1		2		3		4	
Species Group		%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
A	Stellifer lanceolatus	100	75	100	32	63	7	100	70
	Penaeus setiferus	100	119	100	36	100	20	92	18
	Symphurus plagiusa	100	22	0	0	25	1	100	11
	Callinectes sapidus	100	37	75	19	63	47	25	<1
	Menticirrhus americanus	92	5	50	<1	0	0	58	2
	Trinectes maculatus	83	5	50	<1	12	<1	25	<1
	Paralichthys lethostigma	75	4	0	0	12	<1	17	<1
	Scophthalmus aquosus	67	2	0	0	12	<1	17	<1
	Micropogonias undulatus	83	4	25	<1	25	<1	67	3
	Penaeus aztecus	58	3	0	0	62	2	58	1
B	Citharichthys spilopterus	33	<1	0	0	0	0	8	<1
	Prionotus tribulus	25	<1	0	0	0	0	8	<1
	Paralichthys dentatus	42	<1	0	0	12	<1	0	0
	Etropus crossotus	58	1	25	<1	0	0	17	<1
	Ophidion marginata	33	<1	25	<1	0	0	0	0
C	Panopeus herbsti	8	<1	50	1	75	5	8	<1
	Palaemonetes vulgaris	8	<1	0	0	50	2	8	<1
	Penaeus duorarum	58	2	50	<1	100	23	58	1
	Opsanus tau	50	<1	25	<1	100	20	8	<1
	Bairdiella chrysura	33	<1	50	<1	87	3	8	<1
	Dasyatis sabina	8	<1	25	<1	100	5	0	0
	Leiostomus xanthurus	8	1	25	<1	62	9	50	1
D	Hypsoblennius hentzi	0	0	0	0	50	<1	8	<1
	Gobiesox strumosus	0	0	0	0	50	1	0	0
	Centropristis striata	0	0	0	0	25	<1	8	<1
	Libinia dubia	8	<1	0	0	25	<1	17	<1
	Neopanope sayi	16	<1	0	0	25	<1	17	<1
E	Libinia emarginata	0	0	0	0	12	<1	8	<1
	Peprilus alepidotus	0	0	25	<1	0	0	8	<1
	Etropus sp.	0	0	25	<1	0	0	8	<1
	Chaetodipterus faber	0	0	0	0	0	0	17	<1
	Brevoortia tyrannus	8	<1	0	0	25	<1	17	1
	Menippe mercenaria	0	0	25	<1	12	<1	0	0
F	Portunus gibbesii	8	<1	50	1	37	2	100	58
	Portunus spinimanus	0	0	50	<1	75	6	100	26
	Callinectes similis	17	<1	0	0	12	<1	75	2
	Callinectes ornatus	0	0	0	0	0	0	75	3
	Larimus fasciatus	0	0	0	0	0	0	67	1
	Ovalipes stephensoni	0	0	0	0	0	0	83	5
	Ovalipes ocellatus	0	0	0	0	0	0	67	3
	Trachypenaeus constrictus	42	<1	0	0	25	<1	83	6
	Lolliguncula brevis	8	<1	25	<1	12	<1	58	1
	Anchoa mitchilli	0	0	0	0	0	0	33	<1
	Cynoscion regalis	0	0	0	0	0	0	33	1
	Menticirrhus littoralis	0	0	0	0	0	0	17	<1
	Cynoscion nothus	25	<1	0	0	0	0	33	<1
G	Citharichthys macrops	0	0	0	0	0	0	33	<1
	Prionotus scitulus	0	0	0	0	0	0	25	<1
	Raja eglanteria	0	0	0	0	0	0	25	<1
	Hepatus epheliticus	0	0	0	0	0	0	33	1
	Pagurus pollicaris	0	0	0	0	0	0	17	<1
	Centropristis philadelphica	8	<1	0	0	0	0	17	<1
	Arenaeus cribrarius	0	0	0	0	0	0	33	<1


SITE GROUPS
SIMILARITY
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
1
2
3
4
A
B
C
D
E
F
G
SPECIES GROUPS
-1.0
-0.6
-0.2
0.2
SIMILARITY
FIDELITY
NEGATIVE <1
LOW ≥1
MODERATE ≥2
HIGH ≥3



WESTERN CHANNEL REACH
Stellifer lanceolatus
SOUTH ISLAND REACH
OCEAN REACH
NUMBER OF INDIVIDUALS
TOTAL LENGTH(mm)
0
10
20
30
40
50
60
70
10
30
50
70
90
110
130
150
170

downestuary, from an average size of 128 mm TL in the Western Channel Reach to 142 mm TL in the Ocean Reach (Fig. 8). This indicates possible movement of S. plagiusa downestuary toward more oceanic waters with growth.

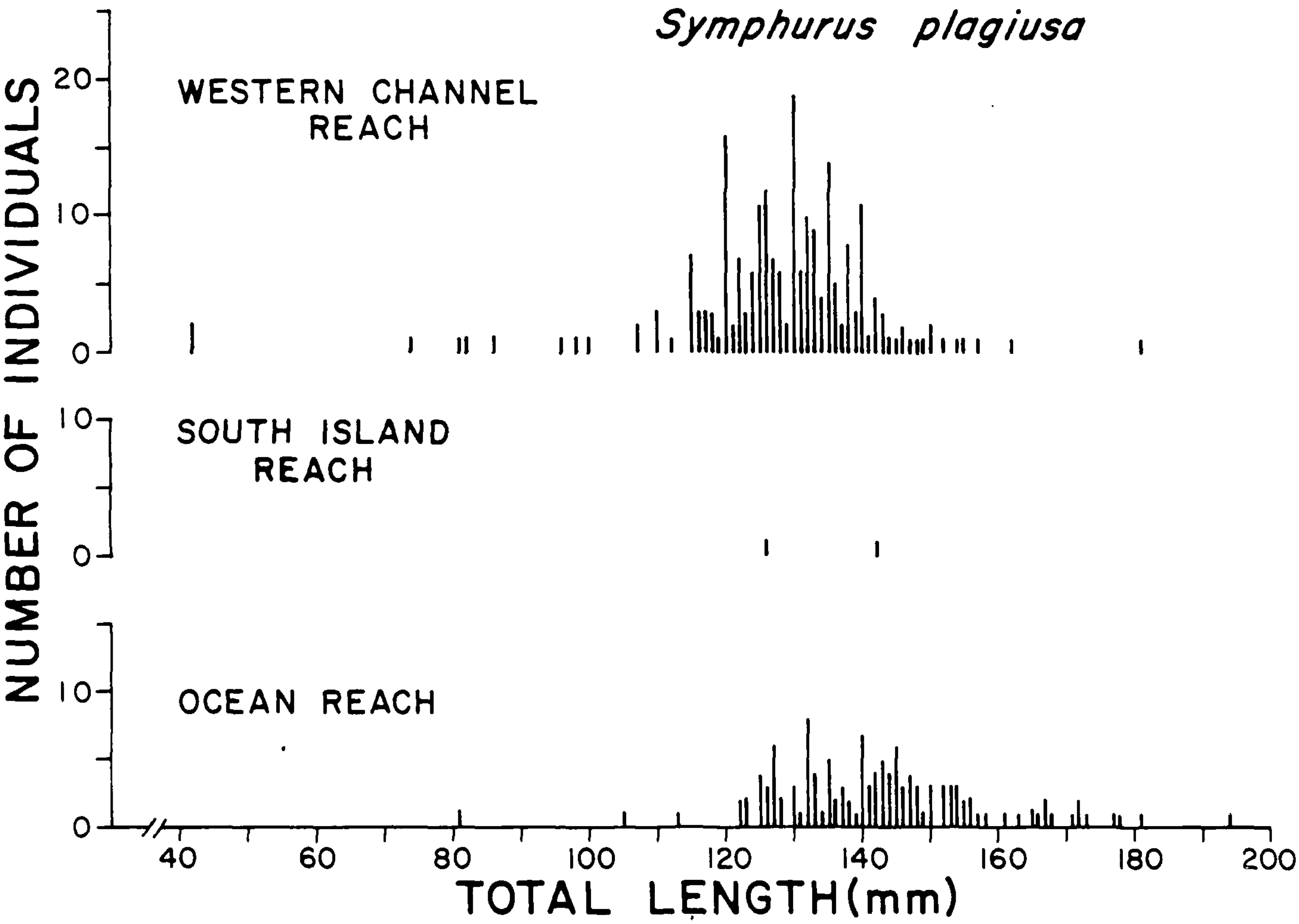
Oyster toadfish: Opsanus tau

Numerically, Opsanus tau ranked as the third most abundant fish and accounted for 6.11% of the catch. O. tau ranked first by weight and comprised 38.39% of the total fish biomass. Catches of O. tau were by far the greatest in the South Island Reach where it occurred in nine of twelve tows (Fig. 9) and was represented by a wide size range of individuals (66-370 mm TL; Fig. 10). Specimens from Western Channel Reach also showed a broad size range (49-320 mm TL), but were present in far fewer numbers, being taken in only six of twelve trawl tows. A single specimen was taken in the Ocean Reach. Within South Island Reach, O. tau was most abundant at the low tide bank stations where catches in three trawl tows comprised 64.9% by number and 76.4% by weight of the overall O. tau catch.

Southern kingfish: Menticirrhus americanus

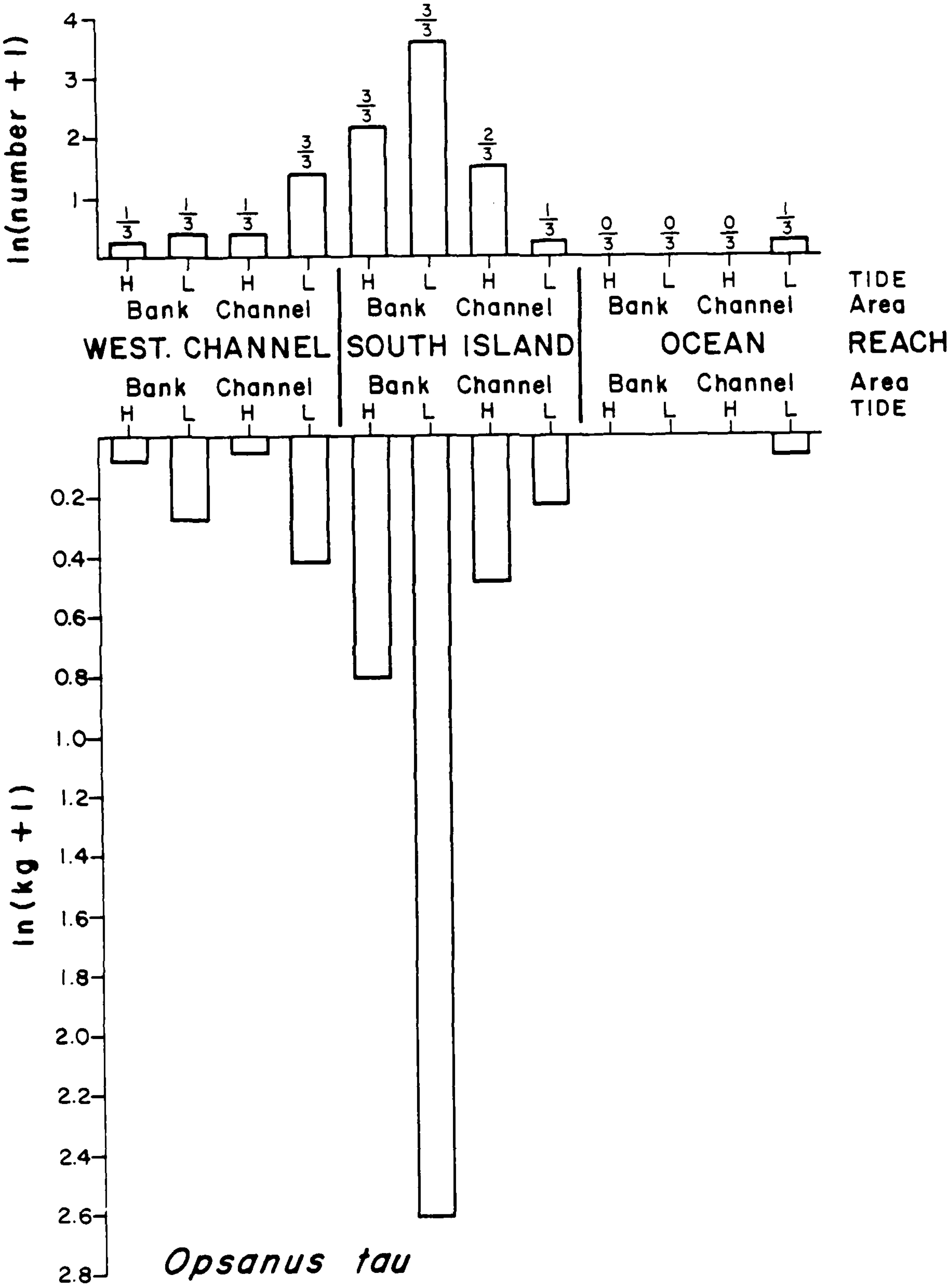
Southern kingfish ranked fourth numerically and ninth by weight, comprising 3.00% and 1.46% of the fish catch, respectively. Greatest numbers of M. americanus were taken in the Western Channel Reach where they were present in eleven of twelve trawl tows (Fig. 11). Specimens from this area ranged in size from 50 to 244 mm TL, although small M. americanus (<140 mm TL) predominated (Fig. 10). Only three M. americanus were taken in the South Island Reach (2 of 12 tows), while twenty-eight specimens were collected in the Ocean Reach (7 of 12 tows). Again, smaller individuals (54-118 mm TL) predominated in the Ocean Reach catch with the greatest numbers of M. americanus taken in the

Figure 8. Length frequency distribution for blackcheek tonguefish, *Symphurus plagiusa*, collected from the Winyah Bay system during October, 1980.



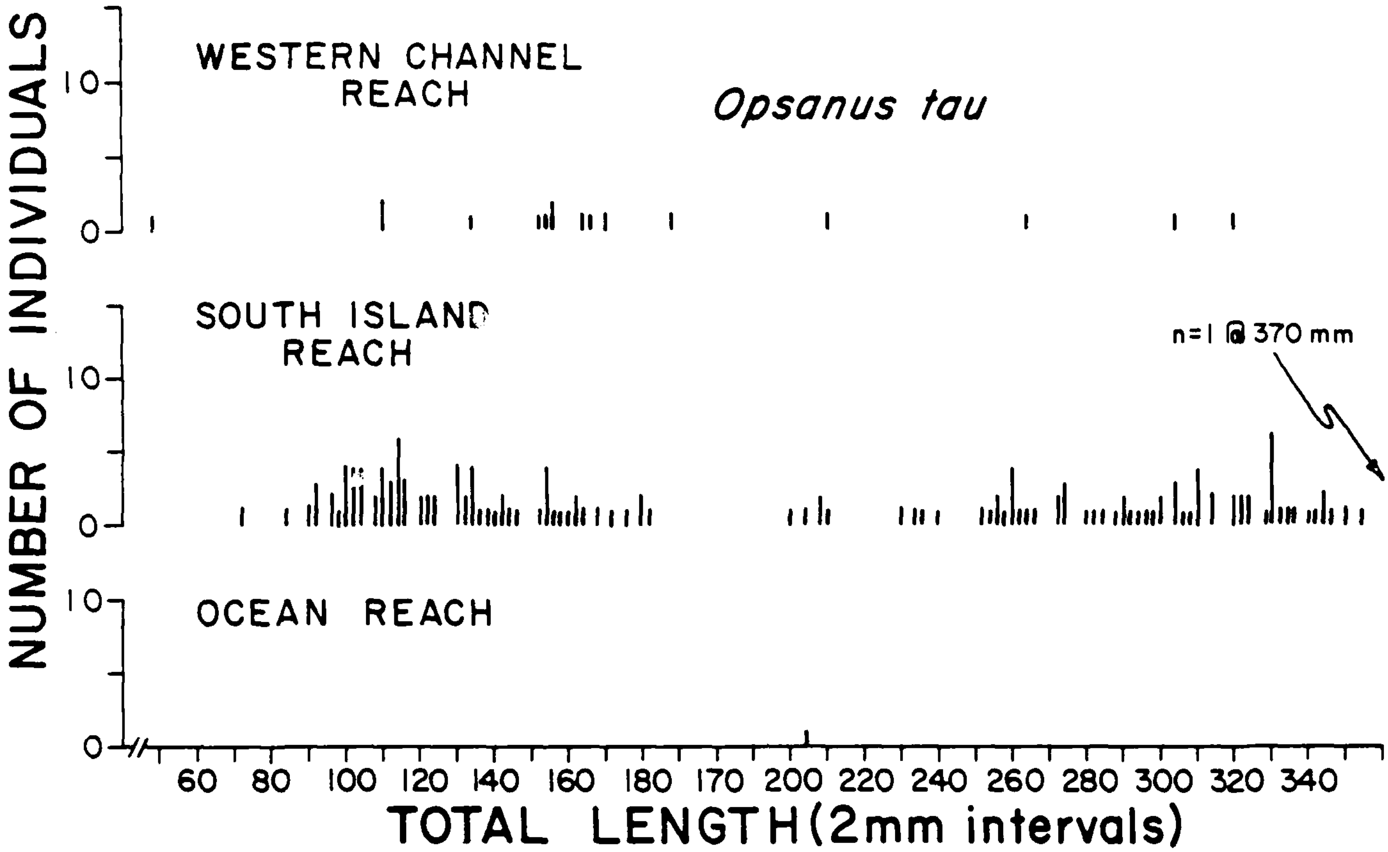
Symphurus plagiusa
NUMBER OF INDIVIDUALS
WESTERN CHANNEL REACH
SOUTH ISLAND REACH
OCEAN REACH
0
10
20
0
10
0
10
40
60
80
100
120
140
160
180
200
TOTAL LENGTH(mm)

Figure 9. Index of relative abundance for oyster toadfish, *Opsanus tau*, collected from the Winyah Bay system during October, 1980. See Fig. 6 for explanation.

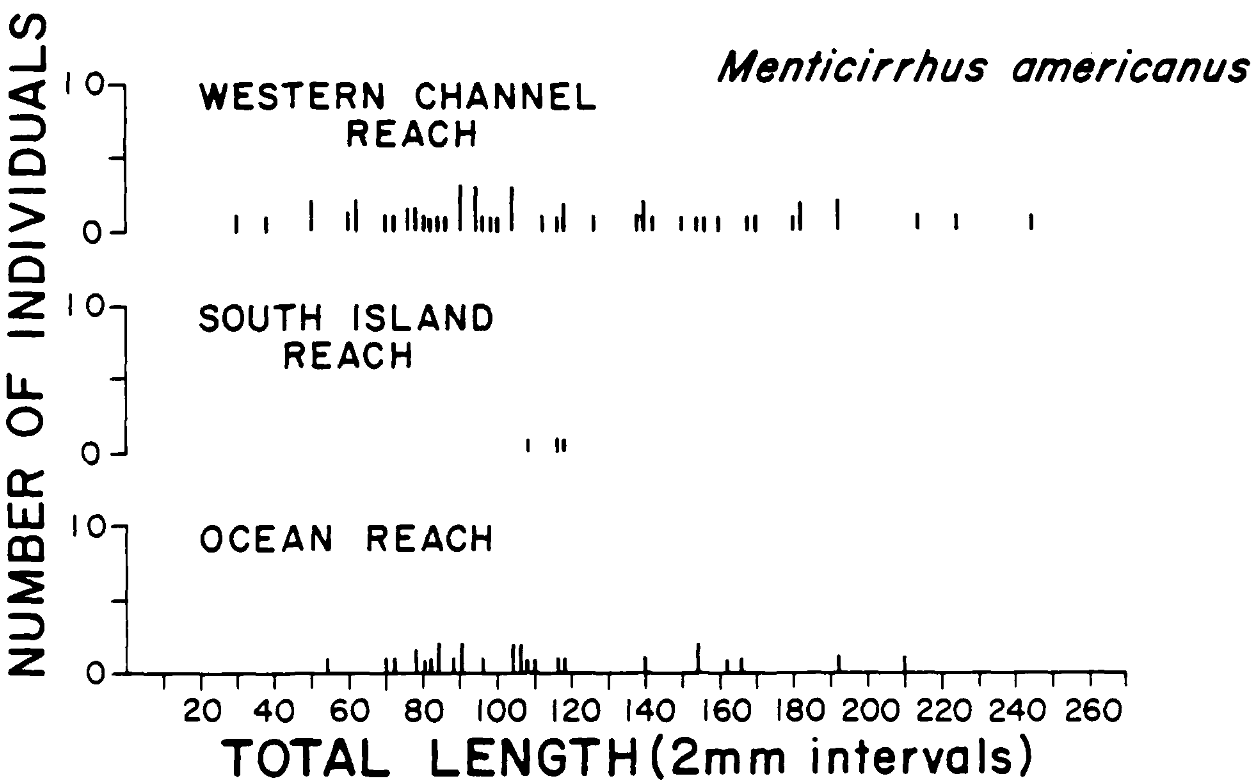


ln(number + 1)
4
3
2
1
1/3
1/3
1/3
3/3
3/3
3/3
2/3
1/3
0/3
0/3
0/3
1/3
H L H L H L H L H L H L
TIDE
Bank Channel Bank Channel Bank Channel
Area
WEST. CHANNEL
SOUTH ISLAND
OCEAN
REACH
Bank Channel Bank Channel Bank Channel
Area
H L H L H L H L H L H L
TIDE
ln(kg + 1)
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
Opsanus tau

Figure 10. Length frequency distribution for oyster toadfish, *Opsanus tau* (upper), and southern whiting, *Menticirrhus americanus* (lower), collected from the Winyah Bay system during October, 1980.

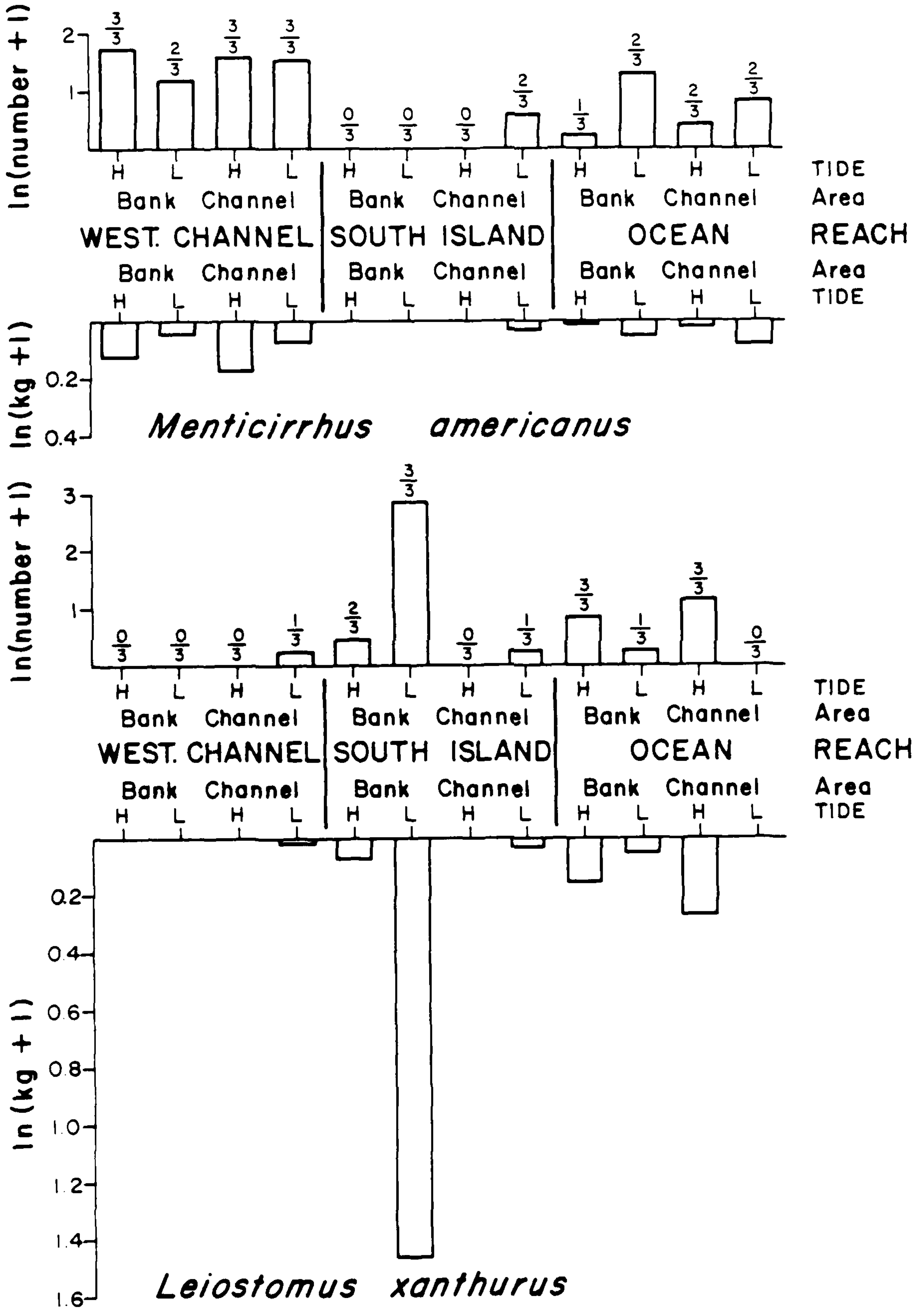


Opsanus tau
NUMBER OF INDIVIDUALS
WESTERN CHANNEL REACH
SOUTH ISLAND REACH
n=1 @ 370 mm
OCEAN REACH
0
10
60 80 100 120 140 160 180 170 200 220 240 260 280 300 320 340
TOTAL LENGTH (2mm intervals)



Menticirrhus americanus
NUMBER OF INDIVIDUALS
WESTERN CHANNEL REACH
SOUTH ISLAND REACH
OCEAN REACH
0
10
20 40 60 80 100 120 140 160 180 200 220 240 260
TOTAL LENGTH (2mm intervals)

Figure 11. Index of relative abundance for southern whiting, *Menticirrhus americanus* (upper), and spot, *Leiostomus xanthurus* (lower), collected from the Winyah Bay system during October, 1980. See Figure 6 for explanation.



ln(number + 1)
3/3 2/3 3/3 3/3 0/3 0/3 0/3 2/3 1/3 2/3 2/3 2/3
H L H L H L H L H L H L TIDE
Bank Channel Bank Channel Bank Channel Area
WEST. CHANNEL SOUTH ISLAND OCEAN REACH
ln(kg + 1)
Menticirrhus americanus
ln(number + 1)
0/3 0/3 0/3 1/3 2/3 3/3 0/3 1/3 3/3 1/3 3/3 0/3
H L H L H L H L H L H L TIDE
Bank Channel Bank Channel Bank Channel Area
WEST. CHANNEL SOUTH ISLAND OCEAN REACH
ln(kg + 1)
Leiostomus xanthurus

area adjacent to the main channel at low tide. The average size of *M. americanus* from the Western Channel Reach (115 mm TL) was not significantly different from that of specimens from the Ocean Reach (111 mm TL).

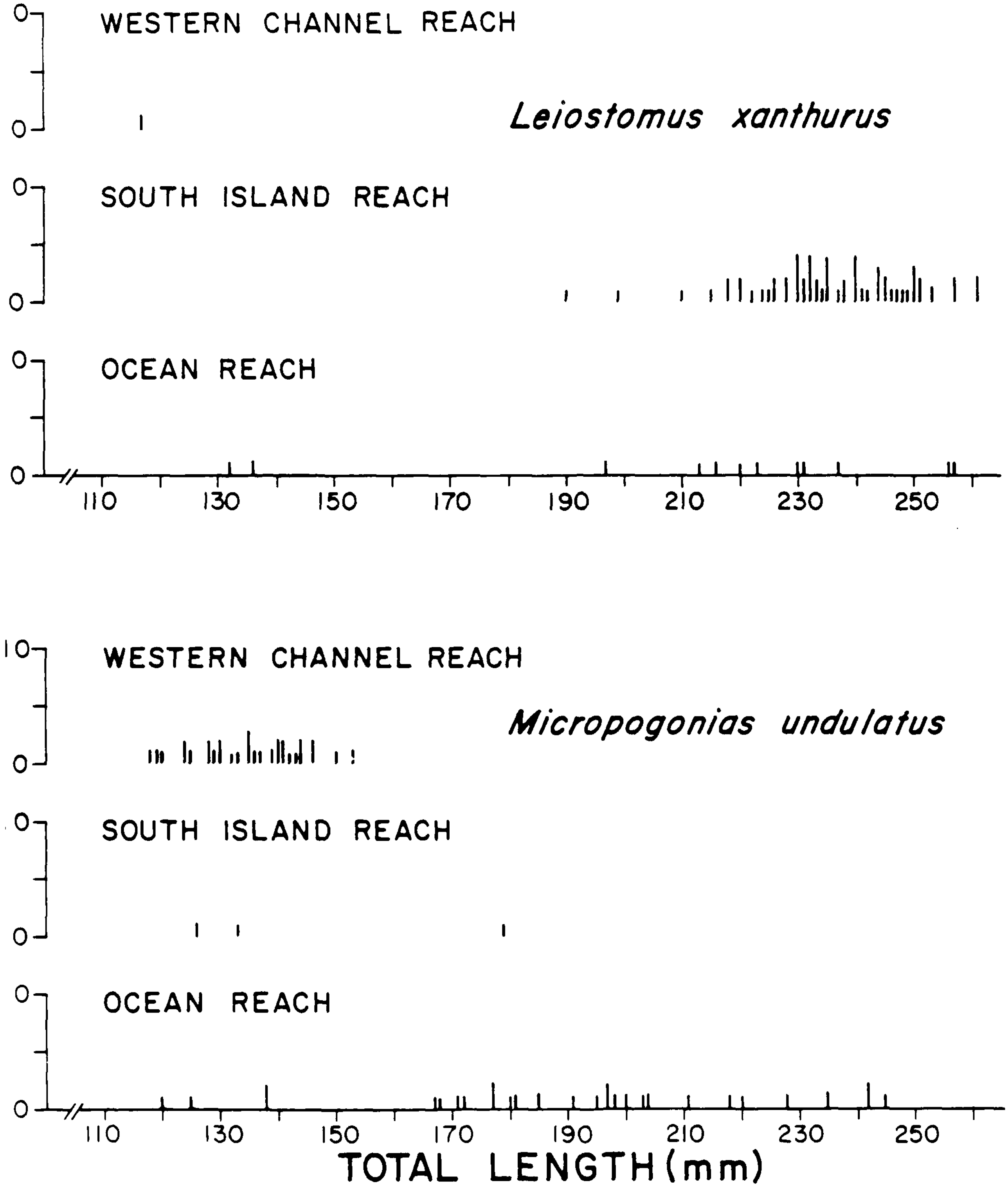
Spot: *Leiostomus xanthurus*

Numerically, *L. xanthurus* ranked fifth among fish species, comprising 2.65% of the total catch. Spot contributed 9.79% of the fish biomass and occupied third position when ranked by weight. Catches of spot were highest in the South Island Reach and in particular, the bank area at low tide where 78.3% of the overall spot catch was collected (Fig. 11). Spot from the South Island Reach ranged in size from 190 to 262 mm TL (Fig. 12) and averaged 235 mm TL. Only one specimen (117 mm TL) was taken in the Western Channel Reach, while seven of twelve tows in the Ocean Reach yielded twelve *L. xanthurus*. Specimens from the Ocean Reach had a size range comparable to that of *L. xanthurus* from the South Island Reach.

Atlantic croaker: *Micropogonias undulatus*

The Atlantic croaker was the sixth most numerically abundant fish and comprised 2.40% of the overall fish catch. It was ranked seventh among fish species by weight and constituted 2.34% of the total fish biomass. Greatest catches of *M. undalatus* were taken in the Western Channel Reach. It was present in ten of twelve trawl tows and was most abundant at low tide stations. Specimens from the Western Channel Reach were relatively small (118-153 mm TL) and averaged 134 mm TL (Fig. 12). Conversely, a broad size range of *M. undulatus* (120-242 mm TL) was taken in the Ocean Reach (8 of 12 trawl tows) and average specimen size was 190 mm TL. Greatest numbers of Atlantic croaker from the Ocean Reach were taken in the main channel (Fig. 13). Only three

Figure 12. Length frequency distribution for spot, *Leiostomus xanthurus* (upper) and croaker, *Micropogonias undulatus* (lower), collected from the Winyah Bay system during October, 1980.



WESTERN CHANNEL REACH
Leiostomus xanthurus
SOUTH ISLAND REACH
OCEAN REACH
110 130 150 170 190 210 230 250
WESTERN CHANNEL REACH
Micropogonias undulatus
SOUTH ISLAND REACH
OCEAN REACH
110 130 150 170 190 210 230 250
TOTAL LENGTH (mm)

Figure 13. Index of relative abundance for croaker, *Micropogonias undulatus* (upper) and hogchocker, *Trinictes maculatus* (lower), collected from the Winyah Bay system during October, 1980. See Figure 6 for explanation.

Table 15. Ranking by numerical abundance for species of decapod crustaceans collected from Winyah Bay during October, 1980.

Species	Total Number	Percent of Catch	Cumulative Percent
Penaeus setiferus	1694	41.91	
Callinectes sapidus	727	17.99	59.90
Portunus gibbesii	681	16.85	76.75
Portunus spinimanus	364	9.01	85.76
Penaeus duorarum	190	4.70	90.46
Trachypenaeus constrictus	77	1.90	92.36
Ovalipes stephensoni	55	1.36	93.72
Panopeus herbsti	51	1.26	94.98
Penaeus aztecus	43	1.06	96.04
Callinectes ornatus	37	0.92	96.96
Ovalipes ocellatus	36	0.89	97.85
Callinectes similis	30	0.74	98.59
Palaemonetes vulgaris	17	0.42	99.01
Libinia dubia	9	0.22	99.23
Hepatus epheliticus	7	0.17	99.40
Neopanope sayi	6	0.15	99.55
Arenaeus cribrarius	5	0.12	99.67
Pagurus longicarpus	3	0.07	99.74
Pagurus pollicaris	3	0.07	99.81
Libinia emarginata	2	0.05	99.86
Libinia sp.	2	0.05	99.91
Menippe mercenaria	2	0.05	99.96
Persephona mediterranea	1	0.02	99.98
TOTAL	4042		

The most abundant species was the penaeid shrimp, Penaeus setiferus which accounted for 41.91% of the total number of decapods (Table 15); whereas the portunid crab Callinectes sapidus, ranked first in biomass comprising 73.45% of the total decapod weight (Table 16).

Blue crab: Callinectes sapidus

The blue crab was the second most numerically abundant crustacean species comprising 17.99% of the crustacean catch. Gravimetrically, however, it ranked first among the crustaceans comprising 73.45% of the total crustacean biomass. Greatest catches were made in the Western Channel and South Island reaches, while only four specimens were taken in the Ocean Reach (Fig. 18). Callinectes sapidus was present in all twelve trawl tows in the Western Channel Reach and was most numerous at the channel stations during low tide. Specimens from the Western Channel Reach showed a broad size range (25-186 mm carapace width), although individuals of C. sapidus with a carapace width greater than 90 mm predominated (Fig. 19). Most specimens (71 %) in the latter category were mature males or "jimmie" crabs. Blue crabs were collected in ten of twelve trawl tows in the South Island Reach and the greatest catches came from the bank area (Fig. 18). Again, small C. sapidus were numerous in the catches, however larger individuals (>130 mm CW) predominated (Fig. 19). Conversely, the larger blue crabs from South Island Reach were primarily mature females or "sooks". Average carapace width was somewhat greater for C. sapidus from the South Island Reach (124 mm CW) than it was for specimens from the Western Channel Reach (112 mm CW).

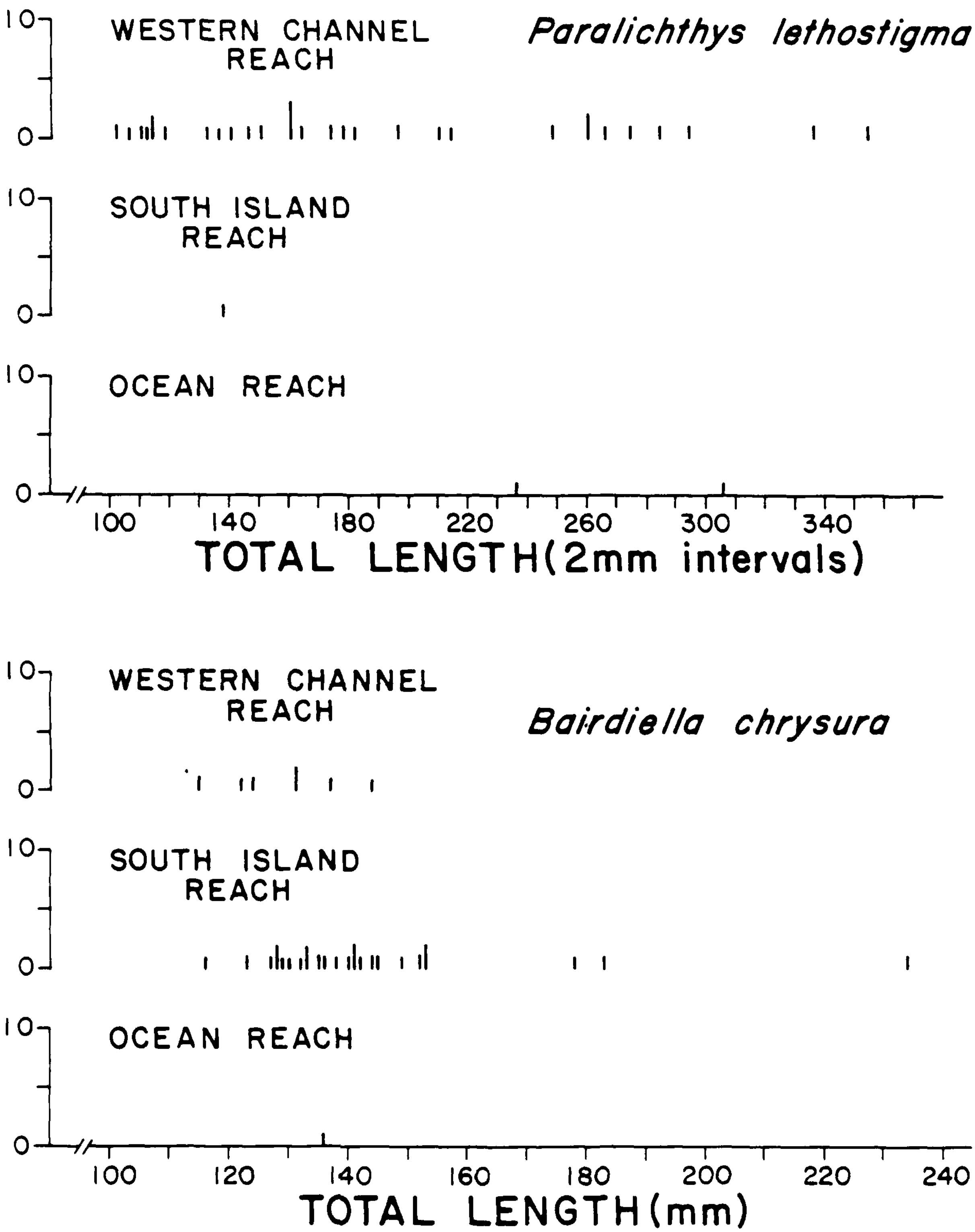
White shrimp: Penaeus setiferus

Numerically, Penaeus setiferus was the most abundant crustacean and accounted for 41.91% of the crustacean catch. It ranked second by weight and

Table 14. Rankings by numbers and weights for families of decapod crustaceans collected from Winyah Bay during October 1980.

Family	Total Number	Percent of Decapod Catch	Cumulative Percent	Number of Species
Penaeidae	2006	49.63		4
Portunidae	1934	47.85	97.48	8
Xanthidae	58	1.43	98.91	3
Palaemonidae	17	0.42	99.33	1
Majidae	13	0.32	99.65	3
Calappidae	7	0.17	99.82	1
Paguridae	6	0.15	99.97	2
Leucosiidae	1	0.02	99.99	1

Family	Total Weight (kg)	Percent of Decapod Catch	Cumulative Percent
Portunidae	96.854	85.23	
Penaeidae	15.721	13.83	99.06
Majidae	0.449	0.40	99.46
Calappidae	0.255	0.22	99.68
Xanthidae	0.216	0.19	99.87
Paguridae	0.123	0.10	99.97
Palaemonidae	0.018	0.02	99.99
Leucosiidae	0.009	0.01	100.00



Paralichthys lethostigma
WESTERN CHANNEL REACH
SOUTH ISLAND REACH
OCEAN REACH
10
0
100
140
180
220
260
300
340
TOTAL LENGTH(2mm intervals)
Bairdiella chrysura
WESTERN CHANNEL REACH
SOUTH ISLAND REACH
OCEAN REACH
10
0
100
120
140
160
180
200
220
240
TOTAL LENGTH(mm)

Figure 17. Length frequency distribution of southern flounder, *Paralichthys lethostigma* (upper), and silver perch, *Bairdiella chrysura* (lower), collected from the Winyah Bay system during October, 1980.

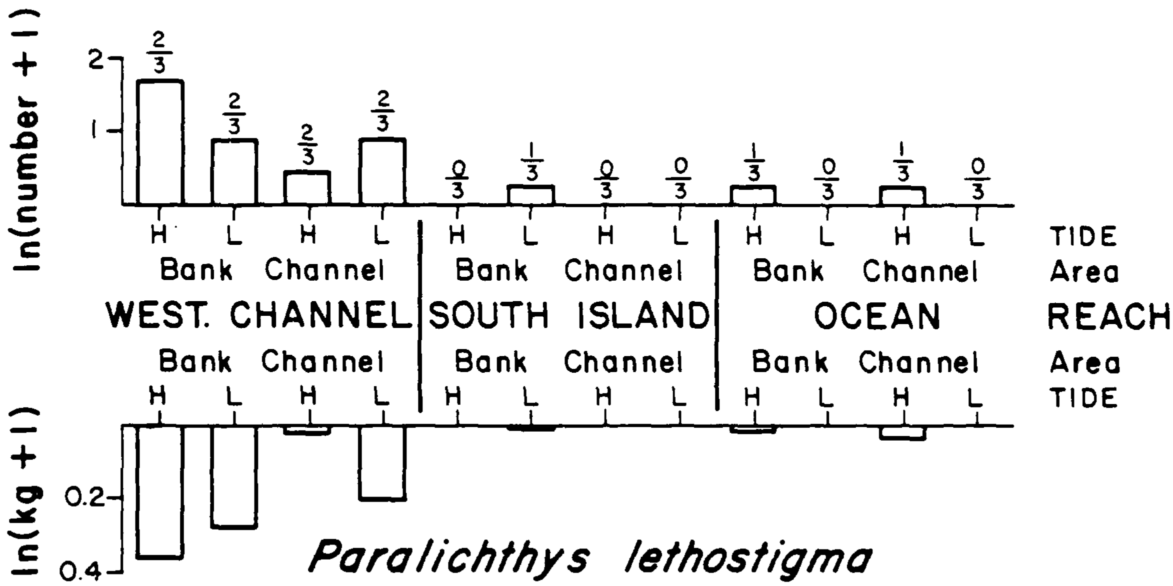
were greatest at the bank station during high tide. Both large and small individuals were taken in the Western Channel Reach and these ranged in size from 102 to 354 mm TL with an average size of 188 mm TL (Fig. 17). Trawl tows in the South Island Reach produced only one P. lethostigma, while 2 specimens were taken in the Ocean Reach.

Silver Perch: Bairdiella chrysura

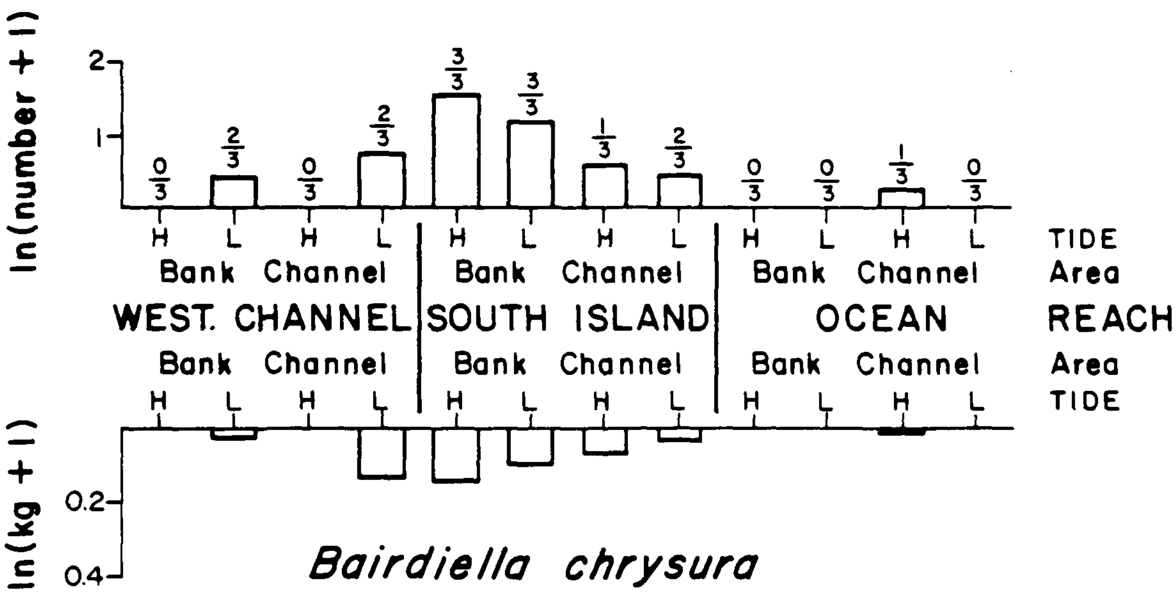
Bairdiella chrysura was the tenth most numerically abundant fish and comprised only 1.22% of the total fish catch. Greatest catches of silver perch were taken in the South Island Reach where it appeared in nine of twelve trawl tows. Bairdiella chrysura was most abundant at the bank stations (Fig. 16). Fewer numbers of B. chrysura were taken in the Western Channel Reach where it occurred only at low tide stations (4 of 6 trawl tows). Only one specimen was taken in the Ocean Reach. Average specimen sizes for the South Island Reach and the Ocean Reach were comparable (129 mm and 143 mm TL, respectively), although several large B. chrysura (>175 mm TL) were taken in the South Island Reach (Fig. 17). Only one B. chrysura was collected in the Ocean Reach.

Decapod Crustaceans

A total of 4,042 decapod crustaceans (eight families, twenty-three species) weighing 113-645 kg were taken in the 36 trawl tows made in the Winyah Bay system during October, 1980. The four species (Penaeus setiferus, P. aztecus, P. duorarum and Trachypenaeus constrictus) in the numerically dominant Penaeidae comprised 49.63% of the decapod catch (Table 14). The Portunidae, the most diverse family (8 species) ranked second in numerical abundance and first by weight (Table 14).

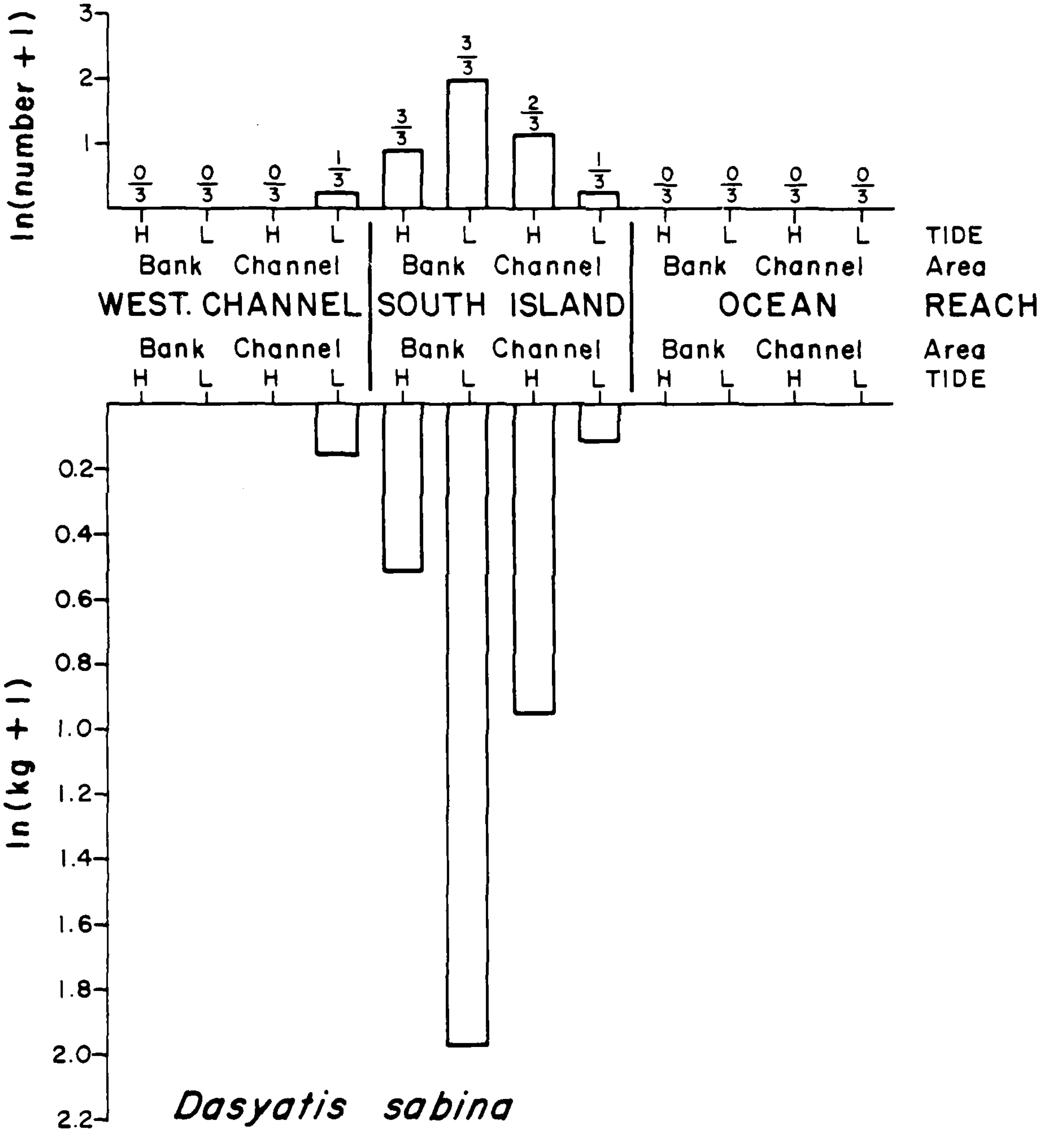


ln(number + 1)
2
1
2/3
2/3
2/3
2/3
0/3
1/3
0/3
0/3
1/3
0/3
1/3
0/3
H L H L H L H L H L H L
TIDE
Bank Channel Bank Channel Bank Channel
Area
WEST. CHANNEL
SOUTH ISLAND
OCEAN
REACH
ln(kg + 1)
0.2
0.4
Paralichthys lethostigma



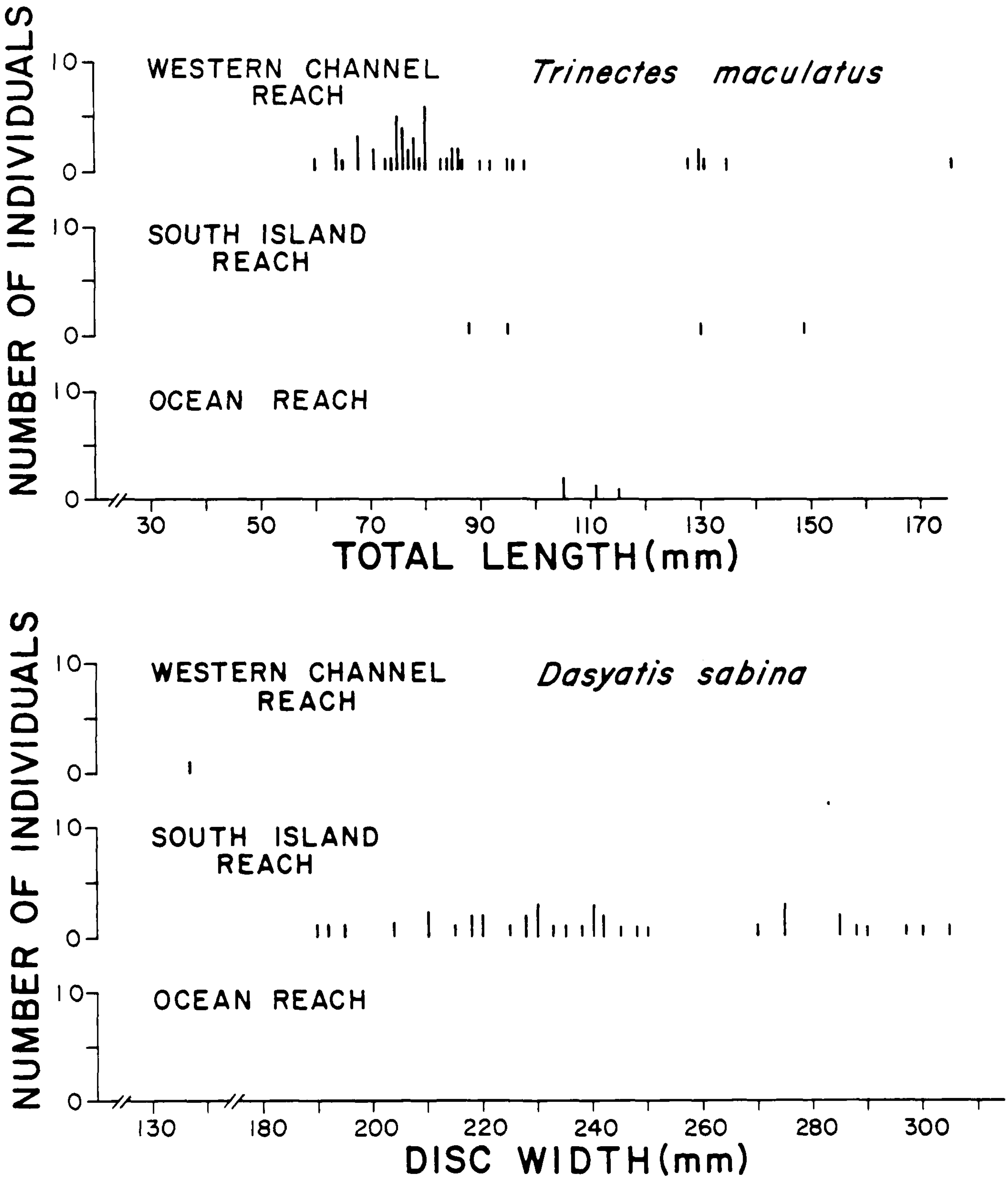
ln(number + 1)
2
1
0/3
2/3
0/3
2/3
3/3
3/3
1/3
2/3
0/3
0/3
1/3
0/3
H L H L H L H L H L H L
TIDE
Bank Channel Bank Channel Bank Channel
Area
WEST. CHANNEL
SOUTH ISLAND
OCEAN
REACH
ln(kg + 1)
0.2
0.4
Bairdiella chrysura

Figure 16. Index of relative abundance for southern flounder, *Paralichthys lethostigma* (upper), and silver perch, *Bairdiella chrysura* (lower), collected from the Winyah Bay system during October, 1980. See Figure 6 for explanation.



ln(number + 1)
0/3
0/3
0/3
1/3
3/3
3/3
2/3
1/3
0/3
0/3
0/3
0/3
H L H L H L H L H L H L TIDE
Bank Channel Bank Channel Bank Channel Area
WEST. CHANNEL SOUTH ISLAND OCEAN REACH
Bank Channel Bank Channel Bank Channel Area
H L H L H L H L H L H L TIDE
ln(kg + 1)
Dasyatis sabina

Figure 15. Index of relative abundance for Dasyatis sabina collected from the Winyah Bay system during October, 1980. See Figure 6 for explanation.



NUMBER OF INDIVIDUALS
WESTERN CHANNEL REACH
Trinectes maculatus
SOUTH ISLAND REACH
OCEAN REACH
TOTAL LENGTH (mm)
NUMBER OF INDIVIDUALS
WESTERN CHANNEL REACH
Dasyatis sabina
SOUTH ISLAND REACH
OCEAN REACH
DISC WIDTH (mm)

Figure 14. Length frequency distribution of hogchockers, *Trinictes maculatus* (upper), and the ray, *Dasyatis sabina* (lower) collected from the Winyah Bay system during October, 1980.

specimens were obtained from the South Island Reach.

Hogchoker: Trinectes maculatus

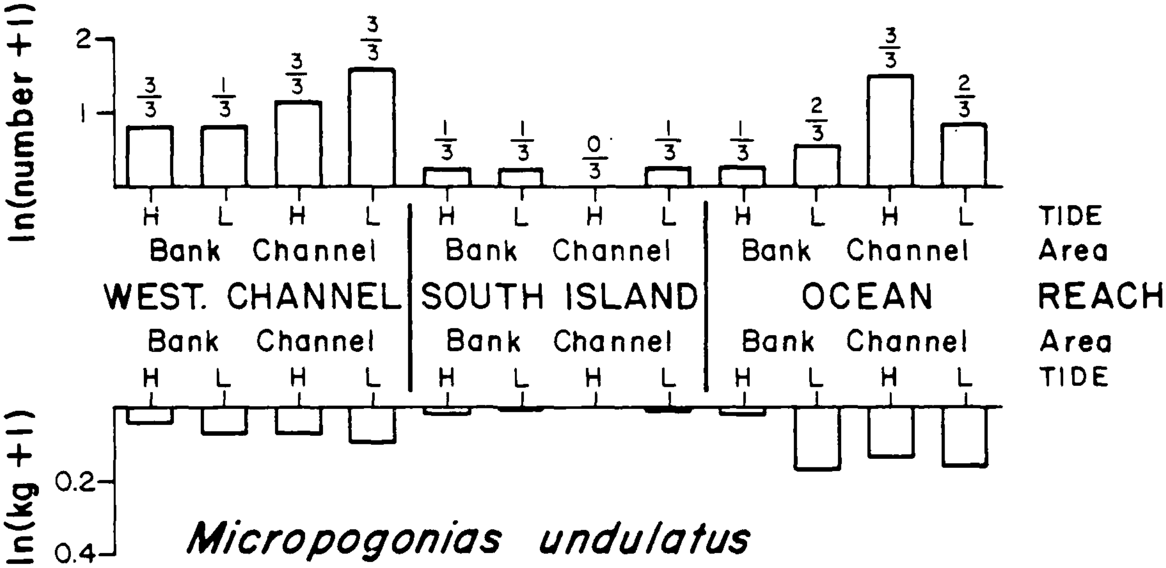
Trinectes maculatus ranked seventh numerically and represented 2.07% of the fish catch. Greatest numbers of T. maculatus were taken in the Western Channel Reach where it occurred in ten of twelve trawl tows (Fig. 13). A majority of hogchokers from this area ranged in size from 60 to 98 mm TL. The average size from the Western Channel Reach was 85 mm TL. Specimens taken downestuary in the South Island and Ocean reaches were somewhat larger than this average, but were represented by far fewer individuals (Fig. 14).

Atlantic stingray: Dasyatis sabina

Numerically, the Atlantic stingray ranked eighth among fish in the catch and represented only 1.47% of the total catch. However, it ranked second by weight, accounting for 22.64% of the total catch. Dasyatis sabina was taken almost exclusively in the South Island Reach. There, it was present in nine of twelve trawl tows and was taken in greatest numbers at bank stations during low tide (Fig. 15). Specimens from the South Island Reach ranged in disc width from 190 to 305 mm with an average disc size of 243 mm (Fig. 14). A single individual, the smallest of the survey (137 mm DW) was taken in the Western Channel Reach. Dasyatis sabina was absent from the trawl catches in the Ocean Reach.

Southern flounder: Paralichthys lethostigma

A total of thirty-five P. lethostigma were collected and it ranked ninth numerically, representing 1.25% of the total fish catch. Catches of P. lethostigma were almost totally restricted to the Western Channel Reach where thirty-two specimens were taken in nine of twelve trawl tows (Fig. 16). Catches


ln(number +1)
2
1
3/3
1/3
3/3
3/3
1/3
1/3
0/3
1/3
1/3
2/3
3/3
2/3
H L H L H L H L H L H L
TIDE
Bank Channel Bank Channel Bank Channel
Area
WEST. CHANNEL
SOUTH ISLAND
OCEAN
REACH
Bank Channel Bank Channel Bank Channel
Area
H L H L H L H L H L H L
TIDE
ln(kg +1)
0.2
0.4
Micropogonias undulatus

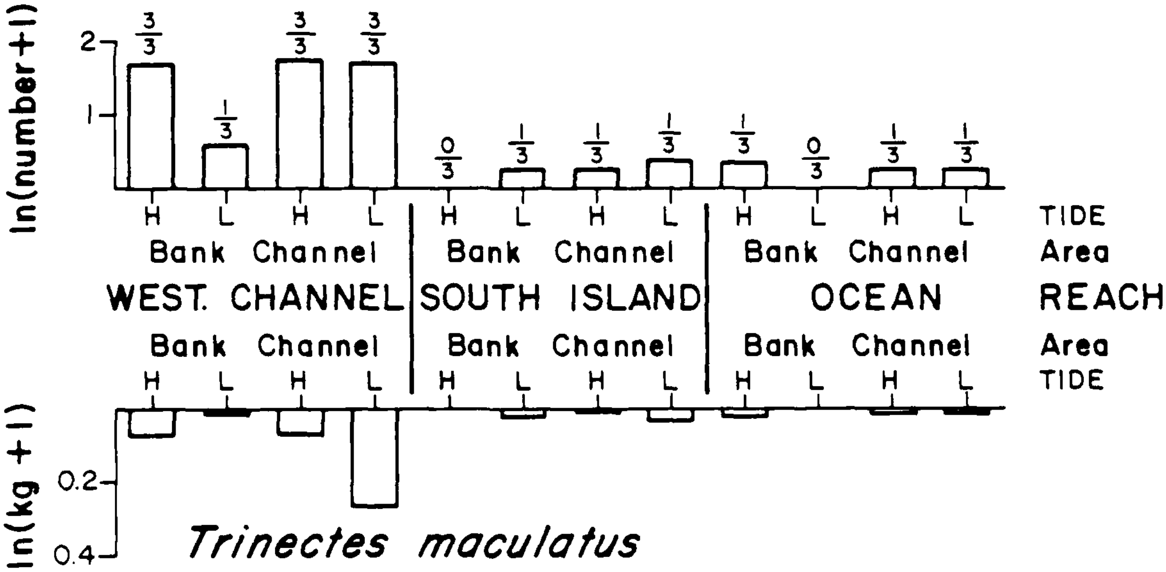
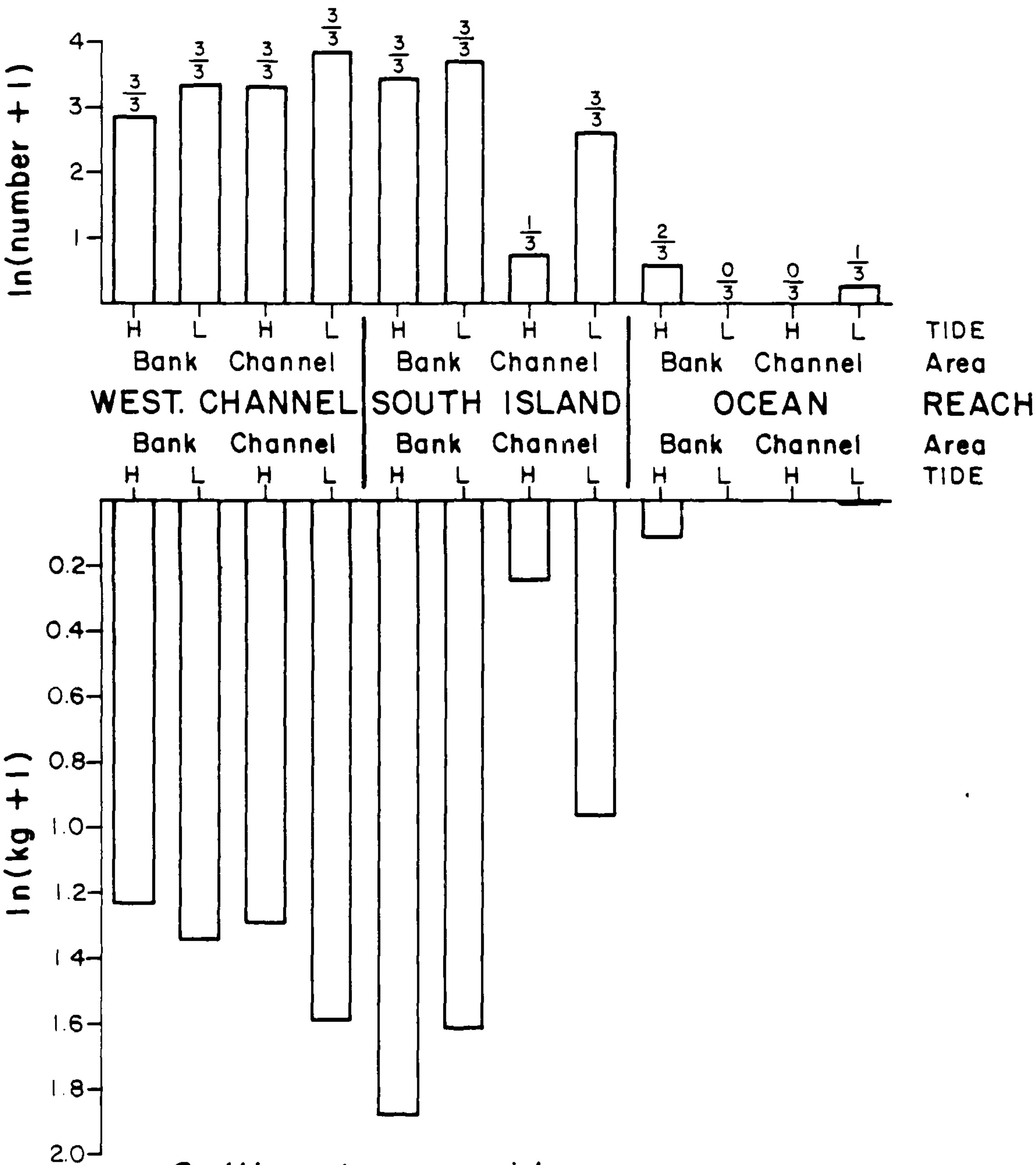

ln(number+1)
2
1
3/3
1/3
3/3
3/3
0/3
1/3
1/3
1/3
1/3
0/3
1/3
1/3
H L H L H L H L H L H L
TIDE
Bank Channel Bank Channel Bank Channel
Area
WEST. CHANNEL
SOUTH ISLAND
OCEAN
REACH
Bank Channel Bank Channel Bank Channel
Area
H L H L H L H L H L H L
TIDE
ln(kg +1)
0.2
0.4
Trinectes maculatus

Table 16. Ranking by weights for species of decapod crustaceans collected from the Winyah Bay system during October, 1980.

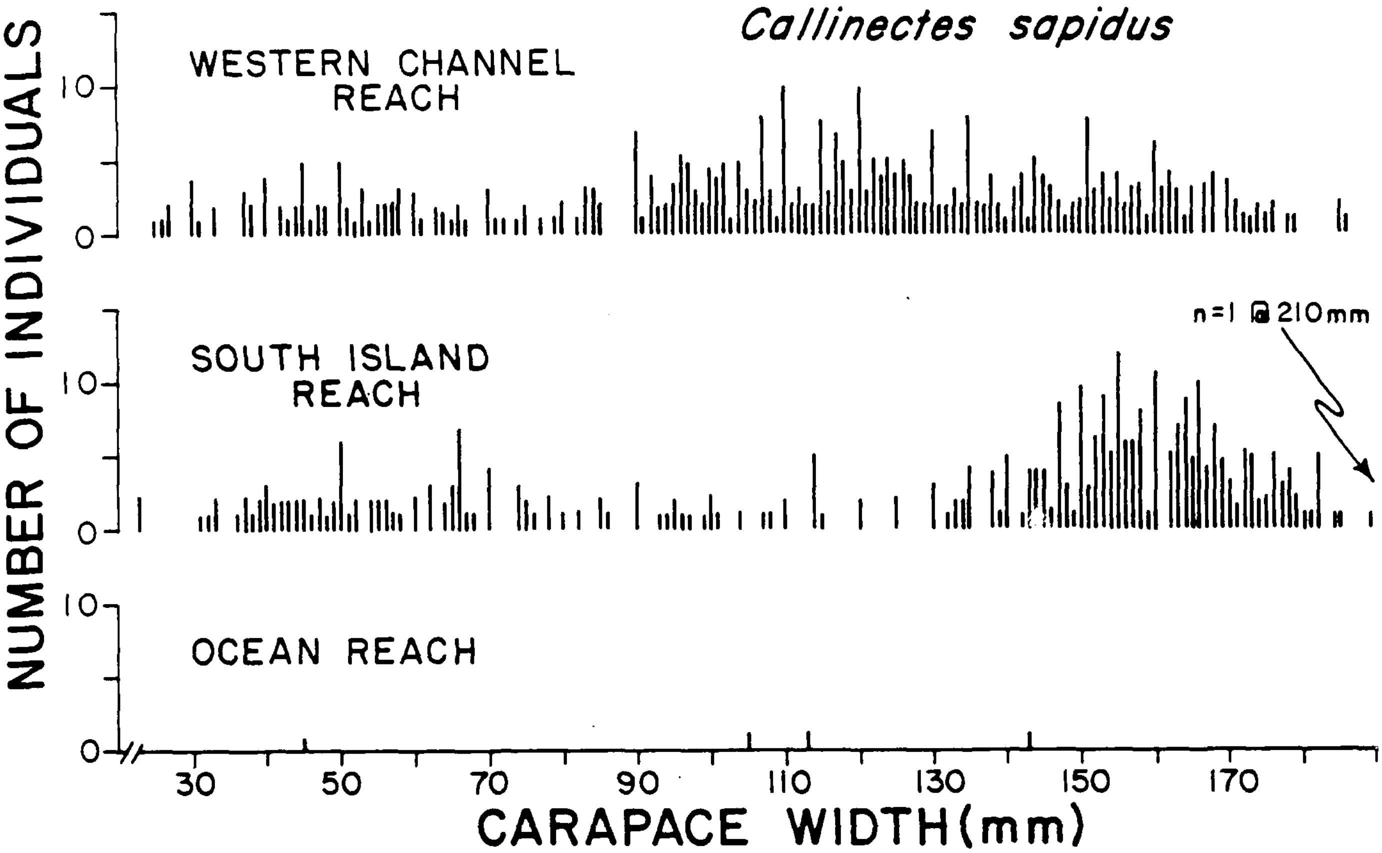
Species	Total Weight (kg)	Percent of Catch	Cumulative Percent
Callinectes sapidus	83.472	73.45	
Penaeus setiferus	14.607	12.85	86.30
Portunus spinimanus	5.469	4.81	91.11
Portunus gibbesii	3.104	2.73	93.84
Ovalipes ocellatus	1.621	1.43	95.27
Ovalipes stephensoni	1.611	1.42	96.69
Callinectes ornatus	0.926	0.81	97.50
Penaeus duorarum	0.595	0.52	98.02
Callinectes similis	0.456	0.40	98.42
Penaeus aztecus	0.350	0.31	98.73
Hepatus epheliticus	0.255	0.22	98.95
Libinia dubia	0.242	0.21	99.16
Arenaeus cribrarius	0.195	0.17	99.33
Penopeus herbsti	0.175	0.15	99.48
Trachypenaeus constrictus	0.169	0.15	99.63
Pagurus pollicaris	0.110	0.10	99.73
Libinia emarginata	0.108	0.10	99.83
Libinia sp.	0.099	0.09	99.92
Menippe mercinaria	0.036	0.03	99.95
Palaemonetes vulgaris	0.018	0.01	99.96
Pagurus longicarpus	0.013	0.01	99.97
Persephona mediterranea	0.009	0.01	99.98
Neopanope savi	0.005	0.01	99.99
TOTAL	113.645		

Figure 18. Index of relative abundance for blue crabs, *Callinectes sapidus*, collected from the Winyah Bay system during October, 1980. See Figure 6 for explanation.

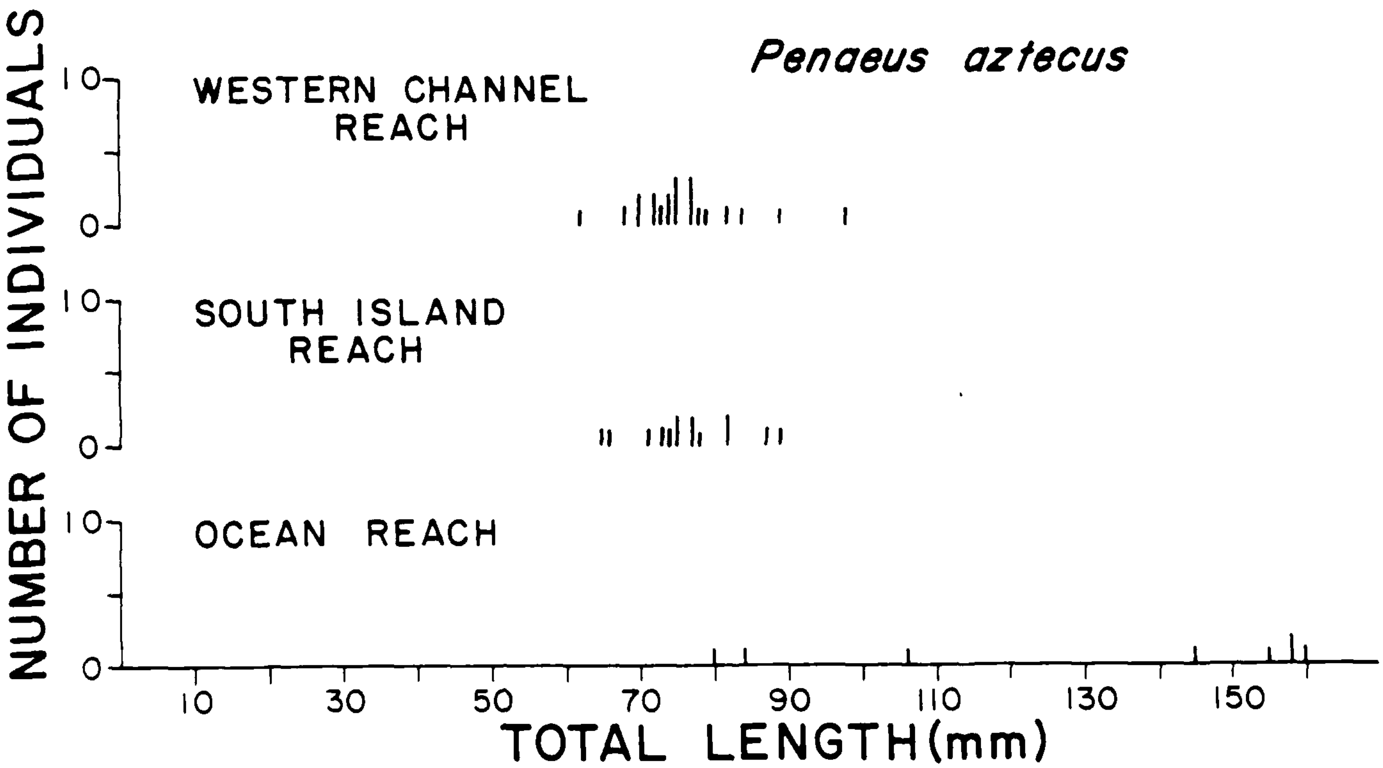


Callinectes sapidus

Figure 19. Length frequency distribution for blue crabs, *Callinectes sapidus* (upper), and brown shrimp, *Penaeus aztecus* (lower), collected from the Winyah Bay system during October, 1980.



Callinectes sapidus
NUMBER OF INDIVIDUALS
WESTERN CHANNEL REACH
SOUTH ISLAND REACH
n=1 @ 210mm
OCEAN REACH
0
10
30
50
70
90
110
130
150
170
CARAPACE WIDTH(mm)



Penaeus aztecus
NUMBER OF INDIVIDUALS
WESTERN CHANNEL REACH
SOUTH ISLAND REACH
OCEAN REACH
0
10
30
50
70
90
110
130
150
TOTAL LENGTH(mm)

comprised 12.85% of the total crustacean biomass. P. setiferus was ubiquitous throughout the study area and occurred in all but one of the trawl tows (Fig. 20). Greatest catches of P. setiferus were made in the Western Channel Reach followed by the South Island Reach. Within both these areas, catches of P. setiferus were consistently greater in trawl tows made during low tide. This suggests that during ebbing stages of the tidal cycle P. setiferus retreats from the shallow marsh areas and concentrates in the deeper channels. The average size of P. setiferus increased down estuary from 110 mm TL at the Western Channel Reach to 136 mm TL at the Ocean Reach (Fig. 21), indicating a movement toward higher salinity ocean waters with growth.

Pink shrimp: Penaeus duorarum

Penaeus duorarum ranked fifth in numerical abundance among crustaceans and comprised 4.82% of the total crustacean catch (Fig. 22). It represented less than 1% of the total crustacean catch by weight (Fig. 23). Among the commercially important species of crustaceans, P. duorarum ranked a distant third in numerical abundance behind C. sapidus and P. setiferus. Greatest catches of P. duorarum were made in the South Island Reach where they occurred in ten of twelve trawl tows (Fig. 22). Within this area, greatest numbers were taken at the bank stations. The average size of P. duorarum from the South Island and Western Channel Reaches was 73 mm TL. Average size of pink shrimp from the Ocean Reach was slightly greater at 87 mm TL (Fig. 23).

Brown shrimp: Penaeus aztecus

Penaeus aztecus was the ninth most numerically abundant crustacean. It constituted less than 1% of the overall crustacean catch by numbers and by weight. It ranked fourth among the commercially important species of crustaceans

Figure 20. Index of relative abundance for white shrimp, *Penaeus setiferus*, collected from the Winyah Bay system during October, 1980. See Figure 6 for explanation.

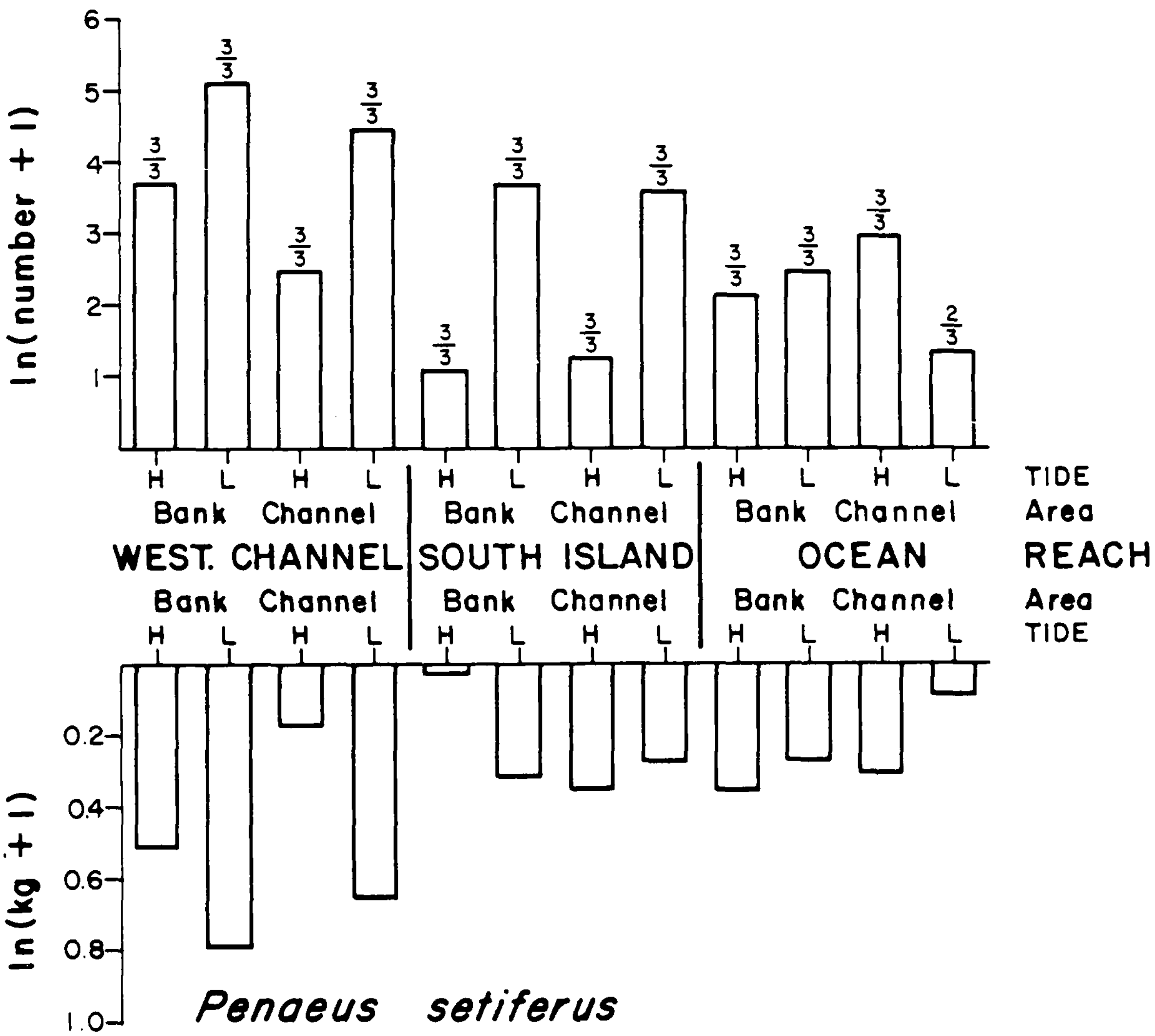
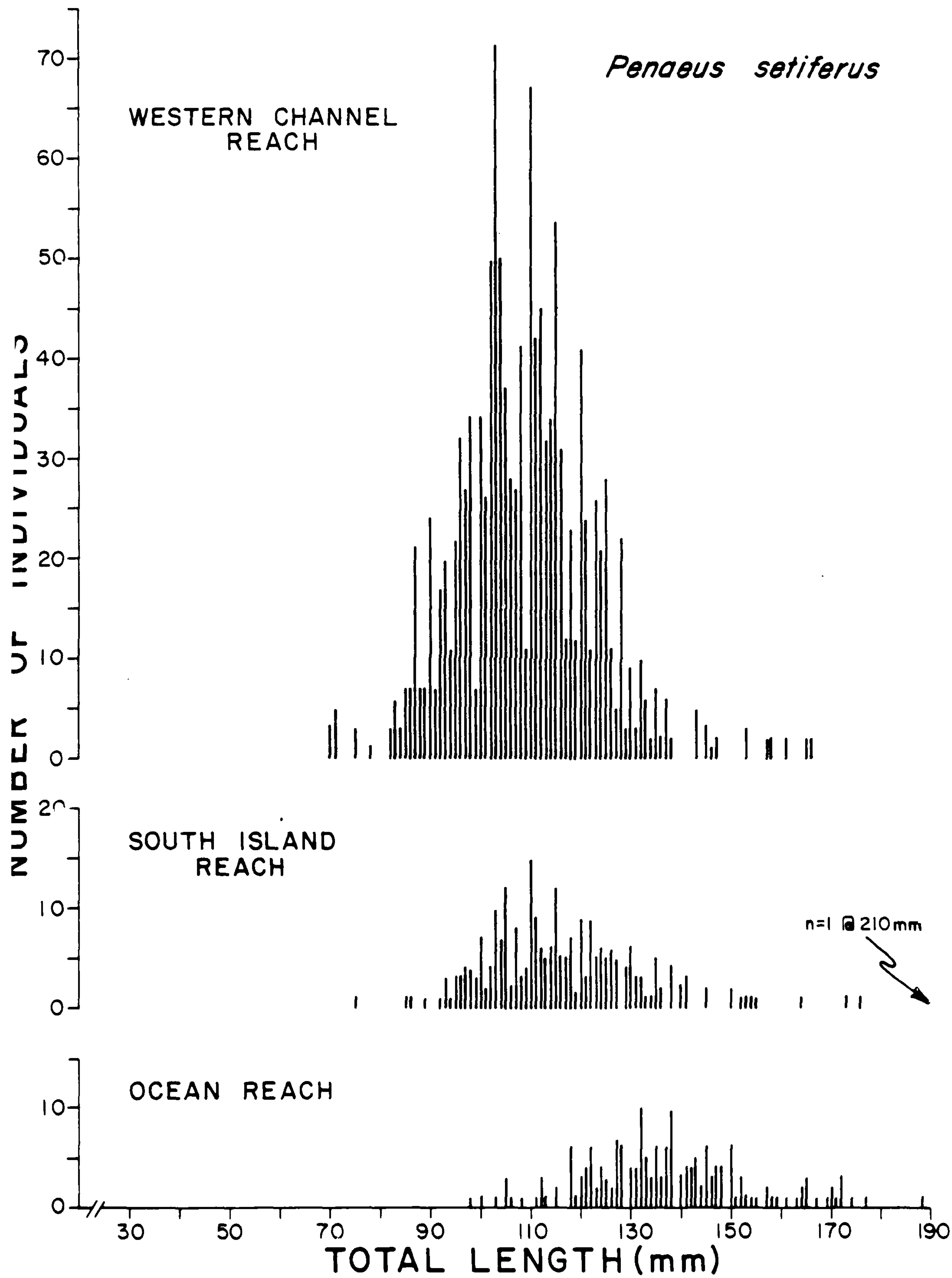
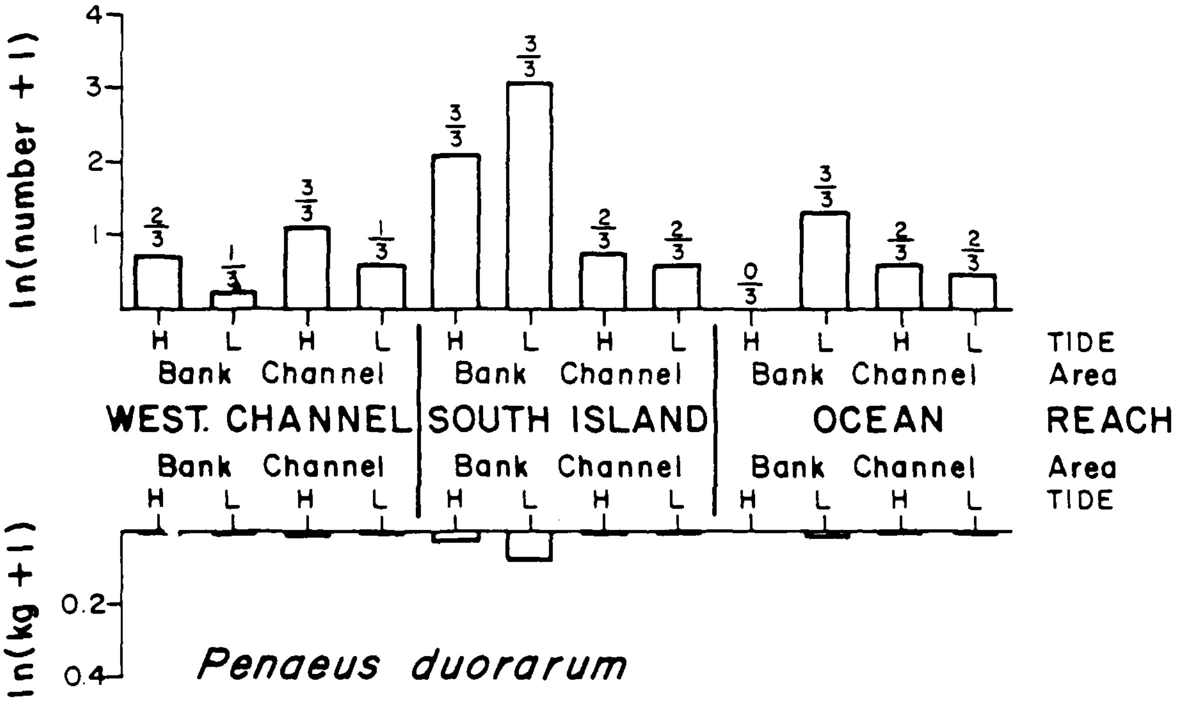

ln(number + 1)
6
5
4
3
2
1
3/3
3/3
3/3
3/3
3/3
3/3
3/3
3/3
3/3
3/3
3/3
2/3
H L H L H L H L H L H L
TIDE
Bank Channel Bank Channel Bank Channel
Area
WEST. CHANNEL
SOUTH ISLAND
OCEAN
REACH
Bank Channel Bank Channel Bank Channel
Area
H L H L H L H L H L H L
TIDE
ln(kg + 1)
0.2
0.4
0.6
0.8
1.0
Penaeus setiferus

Figure 21. Length frequency distribution of white shrimp, *Penaeus setiferus*, collected from the Winyah Bay system during October, 1980.



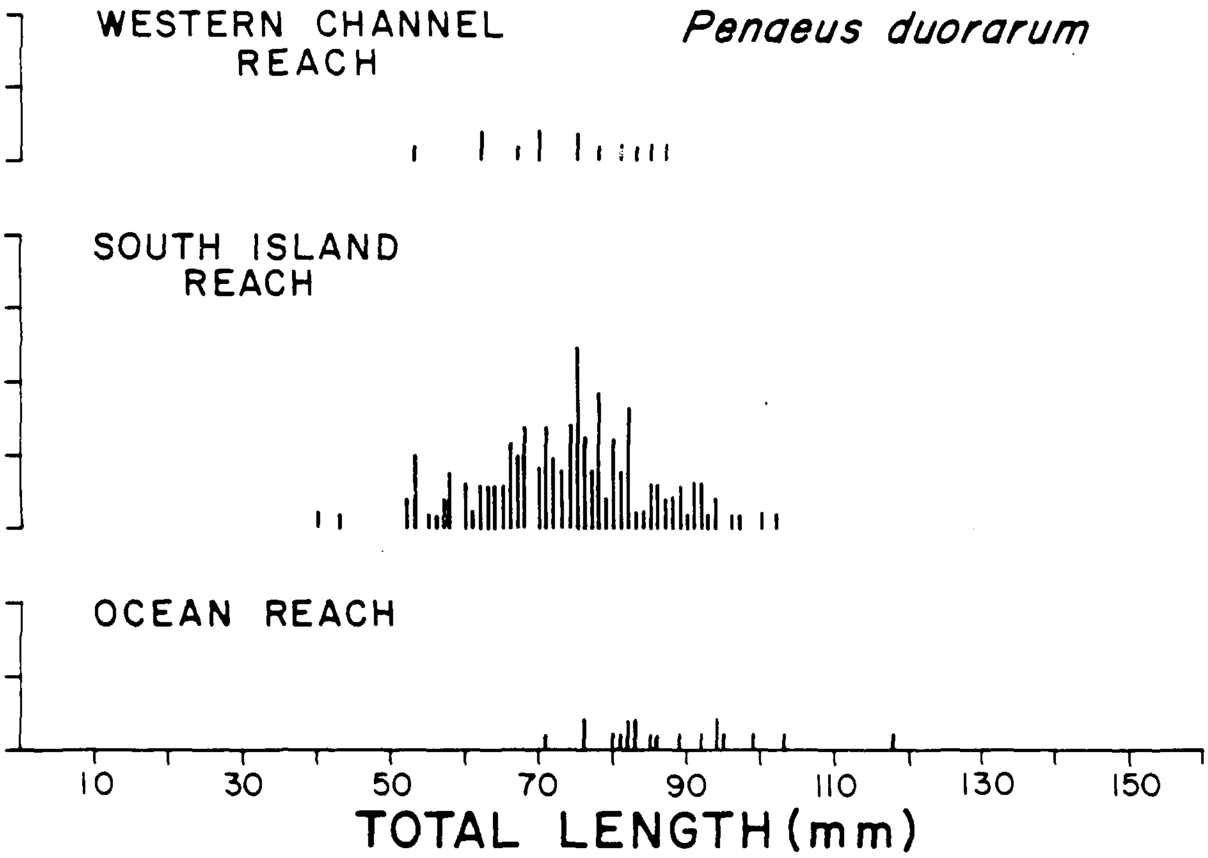
Penaeus setiferus
WESTERN CHANNEL REACH
SOUTH ISLAND REACH
n=1 @ 210mm
OCEAN REACH
NUMBER OF INDIVIDUALS
0
10
20
30
40
50
60
70
30
50
70
90
110
130
150
170
190
TOTAL LENGTH (mm)

Figure 22. Index of relative abundance for pink shrimp, *Penaeus duorarum*, collected from the Winyah Bay system during October, 1980. See Figure 6 for explanation.



Penaeus duorarum

Figure 23. Length frequency distribution of pink shrimp, *Penaeus duorarum*, collected from the Winyah Bay system during October, 1980.



WESTERN CHANNEL REACH
Penaeus duorarum
SOUTH ISLAND REACH
OCEAN REACH
10
30
50
70
90
110
130
150
TOTAL LENGTH (mm)

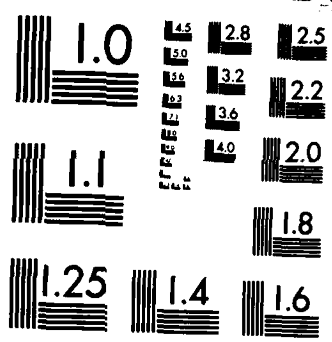
AD-A152 923 BENTHIC AND NEKTONIC STUDIES OF WINYAH BAY FOR THE PROPOSED CHANNEL DEEPE..(U) SOUTH CAROLINA WILDLIFE AND MARINE RESOURCES DEPT CHARLESTON M.. P M HINDE ET AL. 2/2

UNCLASSIFIED FEB 81 DACW60-80-C-0029 F/G 8/1 NL

END

FILMED

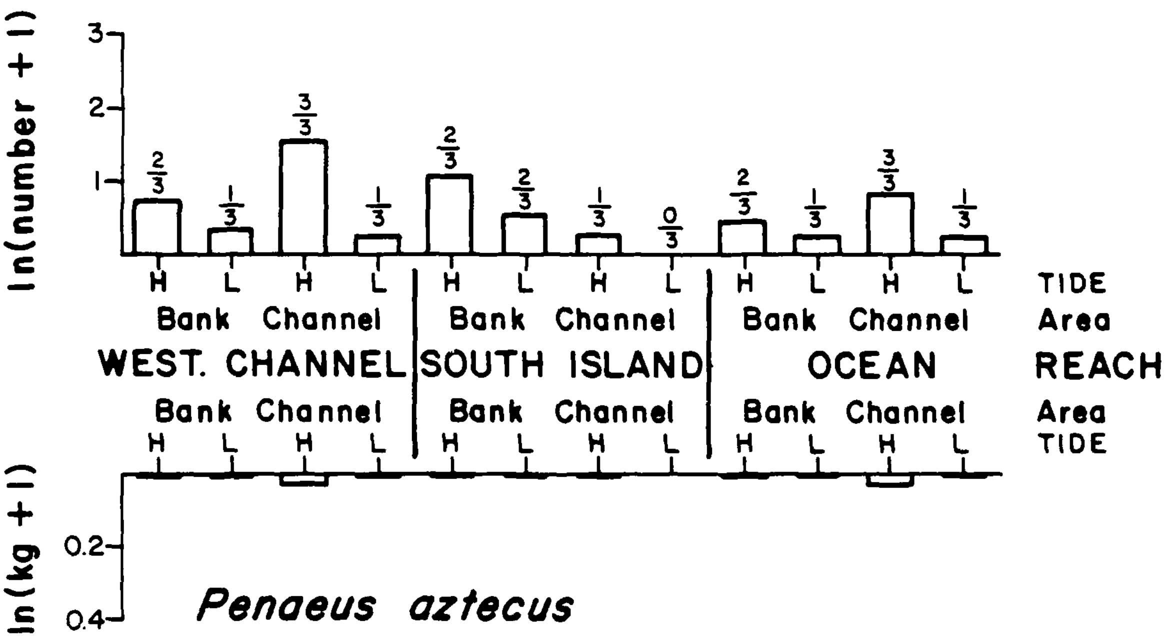
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

taken during the study. The greatest catches of brown shrimp occurred at the Western Channel and South Island reaches (Fig. 24). The average size of *P. aztecus* for both these areas was the same (76 mm TL), however specimens taken in the Ocean Reach were significantly larger averaging 130 mm TL (Fig. 19). As with the other penaeids, this trend seems indicative of a movement oceanward with growth.

Figure 24. Index of relative abundance of brown shrimp, *Penaeus aztecus*, collected from the Winyah Bay system during October, 1980. See Figure 6 for explanation.



ln(number + 1)
3
2
1
2/3
1/3
3/3
1/3
2/3
2/3
1/3
0/3
2/3
1/3
3/3
1/3
H L H L H L H L H L H L
TIDE
Bank Channel Bank Channel Bank Channel
Area
WEST. CHANNEL
SOUTH ISLAND
OCEAN
REACH
Bank Channel Bank Channel Bank Channel
Area
H L H L H L H L H L H L
TIDE
ln(kg + 1)
0.2
0.4
Penaeus aztecus

III. Benthic Ecology: Quantitative Grab Samples

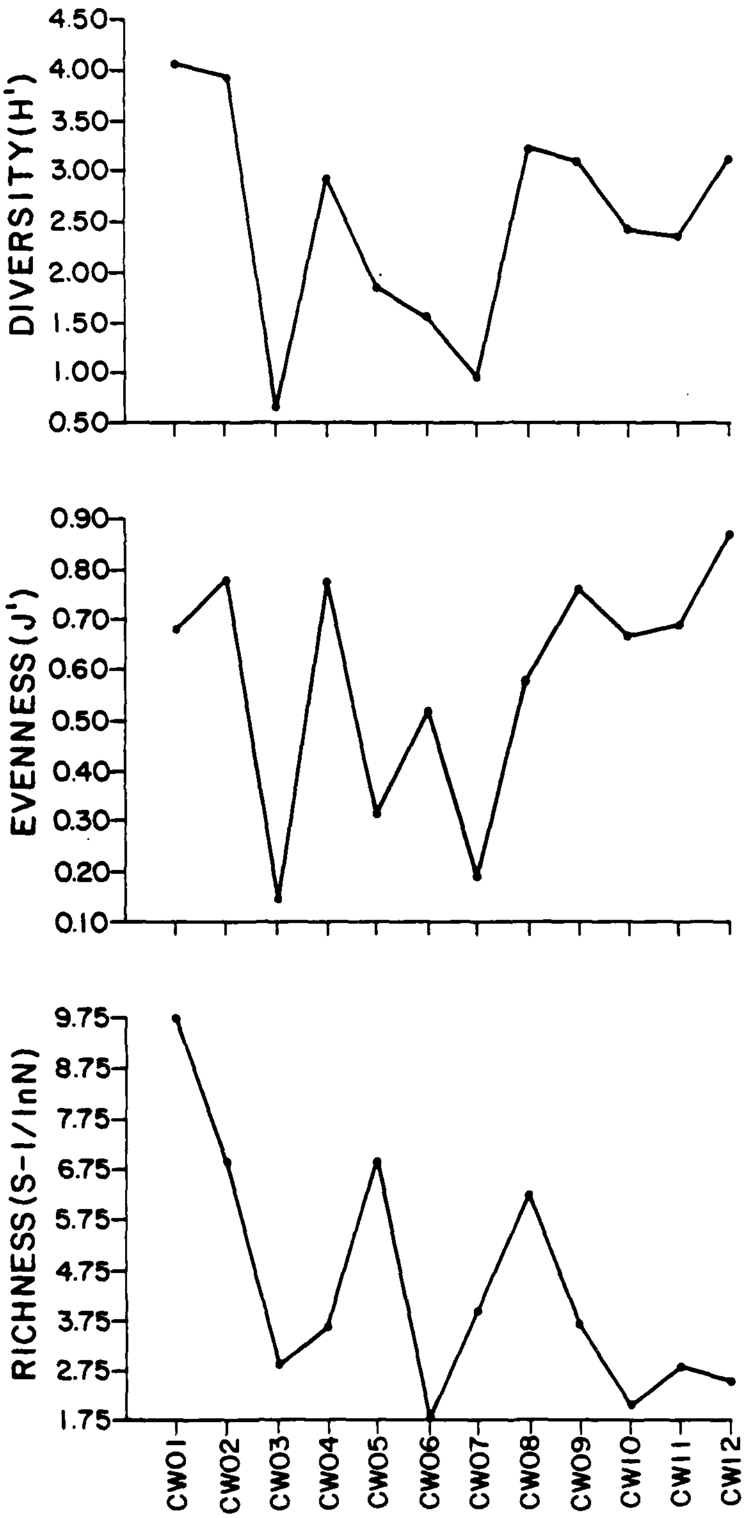
General

A total of 16,281 individuals distributed among 154 taxa were collected counted and identified to the genus or species level in most cases. The species taken in grab samples from each of the 12 benthic sampling sites are reported in Appendix 1, along with their estimated densities in numbers m^{-2}. Estimates were based on three 0.10 m^2 Van Veen grab samples taken at each station except CW04. The densities reported for this station represent the total number of individuals taken in a single grab sample. Only one sample was taken at station CW04 because strong currents and winds as well as the presence of very hard-packed clay substrate prevented the grab from penetrating the bottom and taking an adequate sample despite numerous trials. No attempt was made to extrapolate species abundances at this station to provide estimated densities in numbers m^{-2} since it was thought that the patchy distribution of most benthic organisms precluded an accurate estimate based on a single grab sample.

Species Diversity

Species diversity values varied considerably throughout the sampling area (Figure 25). Diversity was highest at the two most seaward sand stations (CW01 and CW02) and lowest at off-shore channel station, CW03. The relatively high diversity at stations CW01 and CW02 is attributable to the presence of an evenly distributed and diverse assemblage of stenohaline marine species, while the low diversity at station CW03 is a consequence of the overwhelming dominance by two opportunistic species, the bivalve *Mulinia lateralis* and the polychaete *Paraprionospio pinnata*. Species diversity was considerably higher at station CW04 than at CW03, largely because of a markedly more even distribution of individuals among the few species collected in the single grab sample.

Figure 25. Diversity (H'), evenness (J') and richess (S-1/lnN) values for benthic macrofauna collected at each of 12 stations in the Winyah Bay area.


DIVERSITY(H')
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
EVENNESS(J')
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
RICHNESS(S-1/lnN)
9.75
8.75
7.75
6.75
5.75
4.75
3.75
2.75
1.75
CW01
CW02
CW03
CW04
CW05
CW06
CW07
CW08
CW09
CW10
CW11
CW12

Diversity values were somewhat lower at channel station CW05 despite an increase in species richness associated with the presence of a diverse community of sessile and motile epifaunal species. The relatively low diversity at station CW05 is a consequence of numerical dominance by the mussel *Brachidontes exustus*. Species diversity was even lower at station CW06 because of a precipitous decline in species richness related to the absence of oyster shell and mussels and, consequently, of a well-developed epifaunal community. In addition, high current velocities and drastic fluctuations in salinity at station CW06 may have created an environment which is inhospitable to most infaunal organisms as well. Station CW07 had greater species richness but was less diverse than CW06 due to the presence of large numbers of *B. exustus*. Finally, despite very low species richness at stations in the upper reach of the sampling area (CW09, CW10, CW11 and CW12), diversity values were relatively high due to the even distribution of individuals among the few euryhaline marine and estuarine endemic species occupying this highly variable environment.

Cluster and Nodal Analyses:

Normal and inverse cluster analyses generated seven site groups and seven species groups, respectively. Cluster dendrograms and nodal constancy and fidelity tables appear in Figures 26 and 27. Table 17 lists the total abundances for each species in a species group at each station in a site group.

Site group 1 is comprised of a single off-shore station (CW01) which is characterized by its relatively constant euhaline salinity, a sandy substrate, and a diverse assemblage of stenohaline and euryhaline marine species. Site group 2 consists of two off-shore stations (CW02 and CW03) both of which are

Figure 26. Normal and inverse cluster dendrograms and nodal constancy table for 83 species of benthic macrofauna collected at 12 stations in the Winyah Bay area.

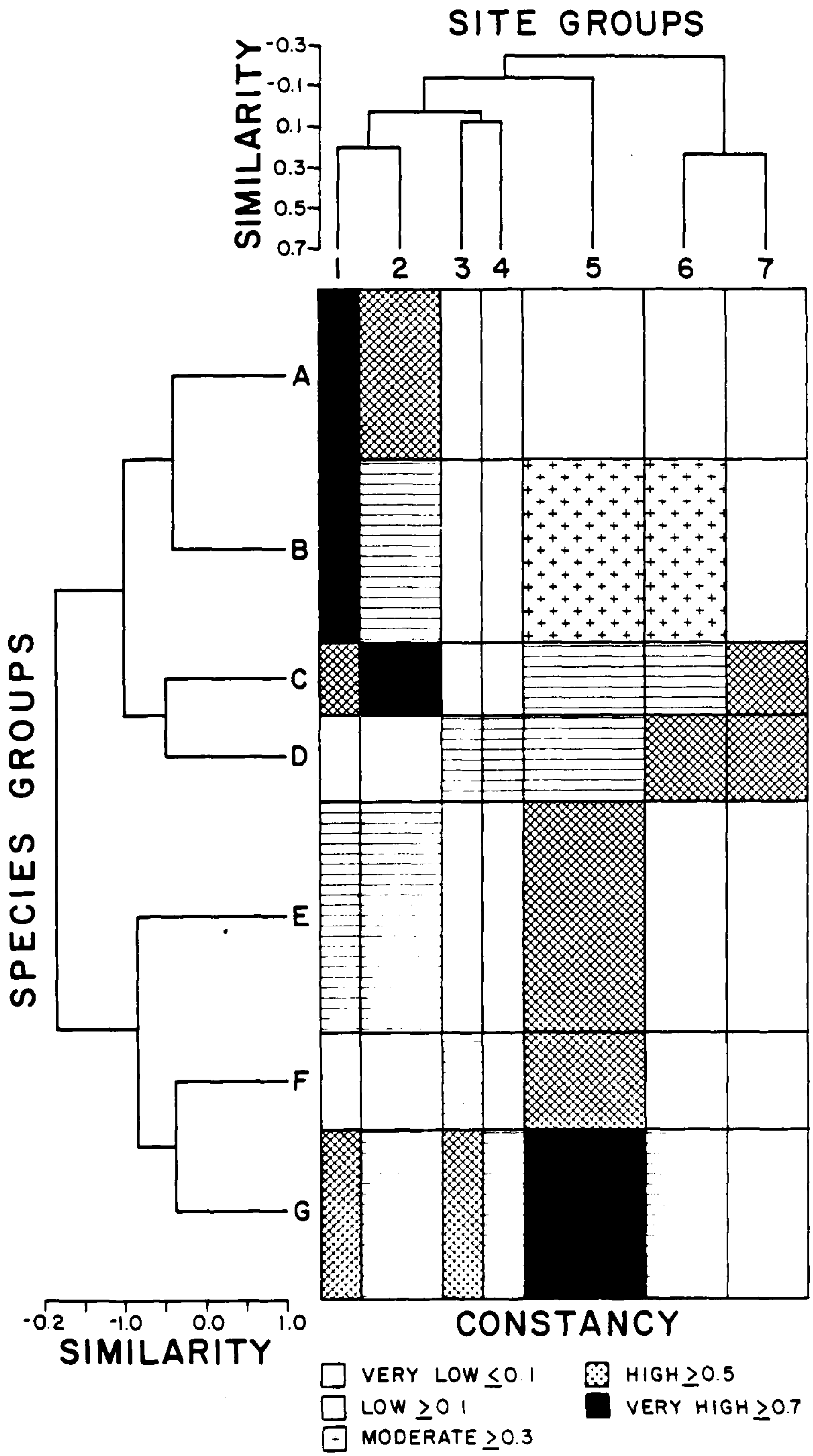
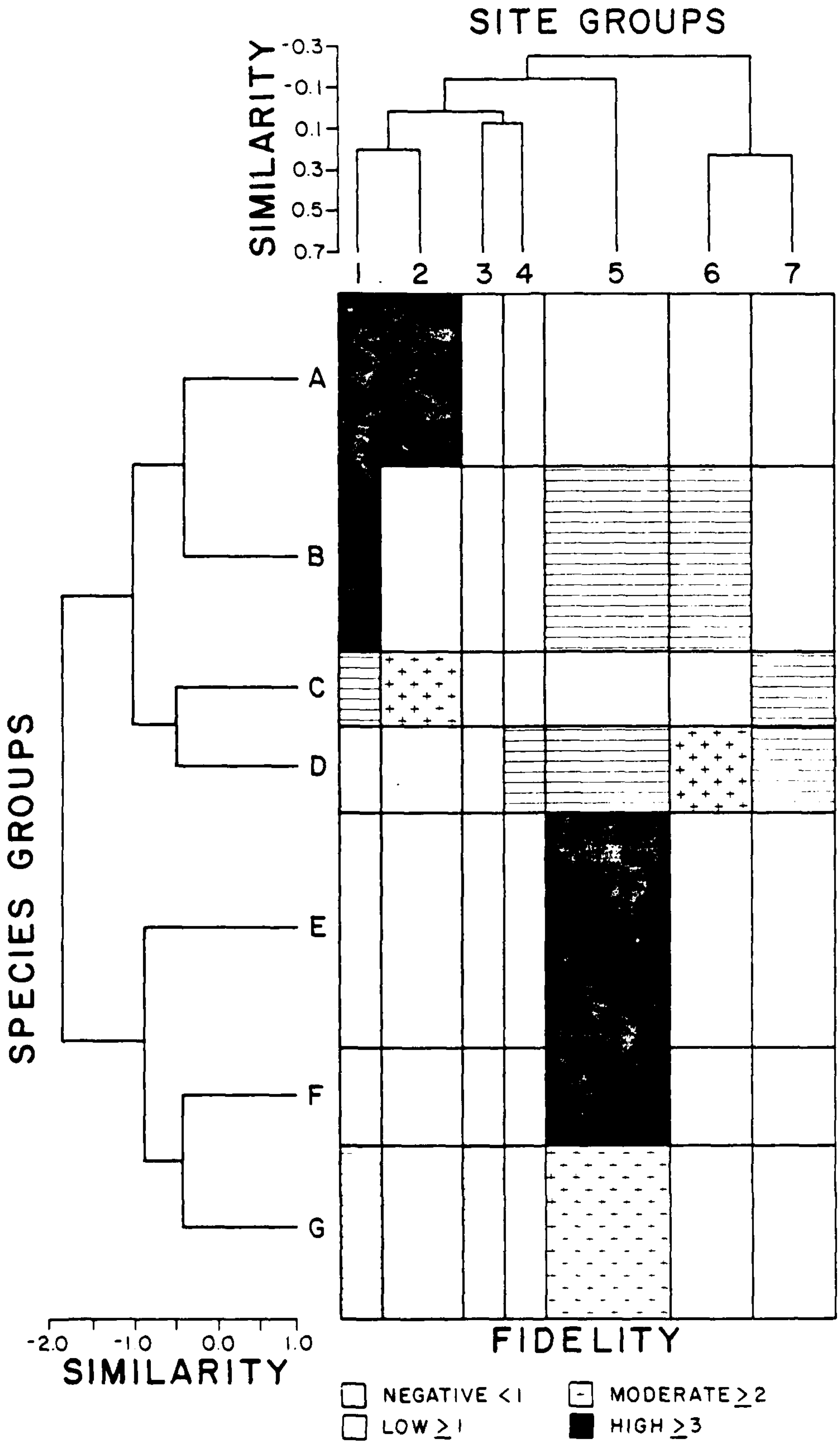

SITE GROUPS
SIMILARITY
-0.3
-0.1
0.1
0.3
0.5
0.7
1
2
3
4
5
6
7
SPECIES GROUPS
A
B
C
D
E
F
G
-0.2
-1.0
0.0
1.0
SIMILARITY
CONSTANCY
VERY LOW ≤0.1
LOW ≥0.1
MODERATE ≥0.3
HIGH ≥0.5
VERY HIGH ≥0.7

Figure 27. Normal and inverse cluster dendrograms and nodal fidelity table for 83 species of benthic macrofauna collected at 12 stations in the Winyah Bay area.


SITE GROUPS
SIMILARITY
-0.3
-0.1
0.1
0.3
0.5
0.7
1
2
3
4
5
6
7
A
B
C
D
E
F
G
SPECIES GROUPS
-2.0
-1.0
0.0
1.0
SIMILARITY
FIDELITY
NEGATIVE <1
LOW ≥1
MODERATE ≥2
HIGH ≥3

(A = amphipod; An = anemo - bivalve; Ba = barnacle; C - cephalochordate; Cu = cumacean; D - decapod; E - echinoderm;
G gastropod; I - isopo - mysid; P = polychaete; T = tunicate).

	Site Group 1 CW01	Site Group 2 CW02	CW03	Site Group 3 CW04	Site Group 4 CW06	Site Group 5 CW05	CW08	CW07	Site Group 6 CW09	CW11	Site Group 7 CW10	CW12
Species Group A												
Trichophoxus floridanus (A)	20	0	0	0	0	0	0	0	0	0	0	0
Tellina alternata (B)	16	0	0	0	0	0	0	0	0	0	0	0
Pseudplatyishnopus floridanus (A)	11	0	0	0	0	0	0	0	0	0	0	0
Branchiostoma caribaeum (C)	30	0	1	0	0	0	0	0	0	0	0	0
Crassinella lunulata (B)	129	6	0	0	0	0	0	0	0	0	0	0
Polychaete sp. A	1	2	0	0	0	0	0	0	0	0	0	0
Edotea montosa (I)	0	4	3	0	0	0	0	0	0	0	0	0
Aricidea cerruti (P)	7	4	0	0	0	0	0	0	0	0	0	0
Hemipholis elongata (E)	3	5	0	0	0	0	0	0	0	0	0	0
Oxyurostylis smithi (Cu)	5	2	2	0	0	0	0	0	0	0	0	0
Amphiodia pulchella (E)	6	1	0	0	0	0	0	0	0	0	0	0
Nephtys bucera (P)	2	1	0	0	0	0	0	0	0	0	0	0
Leucon americanus (Cu)	0	0	1	0	0	0	0	0	0	0	0	0
Cerapus tubularis (A)	1	6	15	0	0	0	0	0	0	0	0	0
Species Group B												
Nemertinean sp. A	40	0	0	0	0	0	0	0	0	0	0	6
Mysidopsis bigelowi (M)	9	0	0	0	0	0	0	0	0	1	0	1
Ancistrosyllis jonesi (P)	13	0	0	0	0	0	2	0	2	0	0	0
Nematoda (undet.)	16	0	0	0	0	0	0	0	2	1	0	0
Glycera dibranchiata (P)	7	2	0	0	0	5	0	0	3	1	0	0
Tellina versicolor (B)	3	1	0	0	0	1	0	0	9	19	0	0
Goniadides carolinae (P)	24	2	1	0	0	1	0	1	0	0	0	0
Hemipodus roseus (P)	20	4	0	0	0	4	1	1	1	0	0	0
Prionospio cristata (P)	163	0	0	0	0	9	0	1	0	0	0	0
Tharyx setigera (P)	4	0	0	0	0	1	0	0	0	0	0	0
Prionospio cirrifera (P)	1	0	0	0	0	1	0	0	0	0	0	0
Cyathura burbancki (I)	3	0	0	1	0	2	0	1	0	0	0	0
Drilonereis magna (P)	1	0	0	0	0	0	0	0	1	0	0	0
Bowmaniella floridana (M)	1	2	0	0	1	0	0	0	0	0	0	0
Gyptis vittata (P)	2	1	0	0	0	2	0	0	0	0	0	0
Species Group C												
Glycinde nordmanni (P)	2	0	7	0	0	0	0	0	4	0	2	0
Magelona sp. (P)	3	0	1	0	0	0	1	0	0	0	0	0
Nemertinean sp. D	1	2	2	0	0	2	1	2	0	0	1	0
Paraprionospio pinnata (P)	1	0	118	0	0	0	0	0	0	0	77	6
Mulinia lateralis (B)	0	45	1541	0	0	0	0	0	0	2	16	10
Sigambra tentaculata (P)	0	1	1	0	0	0	0	0	0	0	8	0

	CW01	CW02	CW03	CW04	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Callinectes sapidus			+					+				+
Panopeus herbstii				+	+		+	+	+			
Xanthidae (undet.)												+
Libinia emarginata							+					
Squilla empusa			+									
Phylum Echinodermata												
Astropecten duplicatus	+											
Asterias forbesi						+						
Ophiuroidea (undet.)		+										
Mellita quinquesperforata	+	+										
Phylum Chordata												
Didemnum candidum		+										
Molgula manhattensis				+	+		+	+				+

	CW01	CW02	CW03	CW04	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Anadara ovalis			+		+		+	+				
Mytilidae (undet.)					+							
Brachidontes exustus				+	+	+	+	+	+	+		
Mulinia lateralis			+							+		+
Macoma balthica										+		
Ostrea equestris	+	+		+	+		+					
Crassostrea virginica				+				+	+			
Mercenaria mercenaria								+				
Hiatella arctica								+				
Martesia cuneiformis				+	+				+			+
Phylum Arthropoda												
Nymphopsis duodorsospinosa					+							
Tanystylum orbiculare					+			+				
Balanus improvisus				+	+	+	+	+	+	+		
Balanus niveus	+	+		+	+		+					
Cleantis planicauda		+										
Caprellidae (undet.)								+	+			
Penaeus duorarum							+					
Penaeus setiferus											+	
Trachypenaeus constrictus											+	
Palaemonetes vulgaris				+								
Alpheus normanni					+		+					
Clibanarius vittatus							+					
Pagurus longicarpus		+	+									
Pagurus pollicaris			+									
Ovalipes stephensoni		+										
Portunus spinimanus			+			+	+					

	CW01	CW02	CW03	CW04	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Phylum Entoprocta												
Lososomella sp.		+										
Pedicellina cernua								+				
Barentsia laxa		+		+	+		+	+				
Phylum Bryozoa												
Alcyonidium polyoum	+	+		+	+	+	+	+				
Anguinella palmata	+			+	+							
Bowerbankia gracilis								+		+		
Aeverrillia setigera				+								
Membranipora arborescens	+			+	+			+				
Membranipora tenuis	+	+		+	+	+	+	+	+	+		
Conopeum tenuissimum		+		+	+	+	+	+				
Electra monostachys		+										
Schizoporella errata	+											
Hippoporina verrilli	+											
Microporella ciliata	+											
Cryptosula pallasiana		+										
Phylum Annelida												
Diopatra cuprea			+									
Sabellaria vulgaris		+		+	+	+	+	+	+	+		
Hydroides dianthus	+	+		+	+	+	+	+				
Phylum Mollusca												
Polinices duplicatus	+	+	+									
Sinum perspectivum			+									
Urosalpinx cinerea							+					
Busycon caraliculatum			+									
Doridella sp.				+				+				

Table 21. Macrofaunal invertebrates in dredge collections from the Winyah Bay area, South Carolina, during autumn 1980.

	CW01	CW02	CW03	CW04	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Phylum Porifera												
Cliona sp.		+		+	+	+			+			
Phylum Cnidaria												
Stomolophus meleagris (polyp)		+				+						
Tubularia crocea		+		+	+		+	+				
Turritopsis nutricula		+		+	+	+			+			
Bougainvillia rugosa		+			+			+				
Garveia franciscana								+		+		
Pandeidae (undet.)		+		+								
Eudendrium sp.							+					
Cuspidella humilis									+			
Campanulina sp.		+	+									
Clytia cylindrica		+		+			+	+		+		+
Clytia kincaidi								+				
Obelia bidentata				+	+		+	+	+	+		
Obelia *dichotoma*					+	+	+	+	+			
Campanopsis sp.				+				+				
Sertularia stookeyi					+							
Plumularia floridana				+	+	+	+	+	+			+
Bunodosoma cavernata				+								
Aiptasia eruptaurantia					+							
Diadumene leucolena				+	+		+	+	+			
Actiniaria (undet.)	+											+
Astrangia astreiformis	+				+							
Phylum Platyhelminthes												
Stylochus ellipticus					+							

IV. Benthic Ecology: Modified Oyster Dredge Collections

The epifauna of Winyah Bay is relatively depauperate in terms of species numbers. The combined species list for all 12 stations sampled in the study area (Table 21) included 83 epifaunal or partly epifaunal macroinvertebrate species. Cnidarians and arthropods accounted for the largest number of species (21 each), followed by mollusks (15) and bryozoans (12). The most widespread species were the bryozoan *Membranipora tenuis*, which occurred at nine of the 12 stations, and the polychaete *Sabellaria vulgaris*, which was found at eight stations. Other ubiquitous species included the hydroid *Plumularia floridana*, the bryozoan *Alcyonidium polyoum*, the polychaete *Hydroides dianthus*, and the barnacle *Balanus improvisus* at seven stations, and the hydroids *Clytia cylindrica* and *Obelia bidentata*, and the bryozoan *Conopeum tenuissimum* at six stations. None of the species collected during the study are believed to be restricted to Winyah Bay and most, if not all, are common to abundant in estuaries and nearshore waters of the state. Several species from stations in the entrance channel (e.g. *Astropecten duplicatus*, *Mellita quinquesperforata*, *Didemnum candidum*) are stenohaline or only moderately euryhaline and were not found in the bay itself; however, all are common to abundant in favorable habitats elsewhere along the coast. The species represented in samples from Winyah Bay proper are known to be characteristically eurytopic.

Epifaunal invertebrate assemblages in estuaries are strongly influenced by both bottom type and local hydrography. Suitable substrates such as shells and rocks must be available for attachment and growth of many sponges, cnidarians, bryozoans, barnacles, and ascidians. Such substrates were generally scarce in the middle reaches of Winyah Bay. In certain areas of the lower reaches and at the mouth of the bay, strong currents have scoured the bottom of fine sediments,

Table 20. Macrofaunal total and percentage abundance data for each of the 15 numercially dominant species collected at stations within the existing channel to Georgetown (stations CW09 and CW11).

A = amphipod; B = bivalve; I = isopod; M = mysid; P = polychaete

SPECIES	STATION CW09 Total Abundance	STATION CW09 Percentage of Total Faunal Abundance	STATION CW11 Total Abundance	STATION CW11 Percentage of Total Faunal Abundance
Streblospio benedicti (P)	35	41.2	5	14.3
Tellina versicolor (B)	9	10.6	19	54.3
Oligochaeta (undet.)	7	8.2	1	2.9
Petricola pholadiformis (B)	6	7.1	0	0.0
Heteromastus filiformis (P)	4	4.7	2	5.7
Milita nitida (A)	4	4.7	0	0.0
Glycinde nordmanni (P)	4	4.7	0	0.0
Glycera dibranchiata (P)	3	3.5	1	2.9
Chiridotea coeca (I)	2	2.4	1	2.9
Nematoda (undet.)	2	2.4	1	2.9
Ancistrosyllis jonesi (P)	2	2.4	0	0.0
Nereis succinea (P)	2	2.4	0	0.0
Mulinia lateralis (B)	0	0.0	2	5.7
Hemipodus roseus (P)	1	1.2	0	0.0
Mysidopsis bigelowi (M)	0	0.0	1	2.9
Total	81	95.5	33	94.5
Total For All Species	85	100.0	35	100.0

Table 19. Macrofaunal total and percentage abundance data for each of the 15 numerically dominant species collected at stations along the proposed western channel turning basin (stations CW10 and CW12).

B = bivalve; I = Isopod; M = mysid; P = polychaete

SPECIES	STATION CW10 Total Abundance	STATION CW10 Percentage of Total Faunal Abundance	STATION CW12 Total Abundance	STATION CW12 Percentage of Total Faunal Abundance
Paraprionospio pinnata (P)	77	36.0	6	8.0
Streblospio benedicti (P)	63	29.4	18	24.0
Sabellaria vulgaris (P)	33	15.4	0	0.0
Mulinia lateralis (B)	16	7.5	10	13.3
Heteromastus filiformis (P)	4	1.9	12	16.0
Oligochaeta (undet.)	6	2.8	9	12.0
Sigambra tentaculata (P)	8	3.7	0	0.0
Nemertinean sp. A	0	0.0	6	8.0
Chiridotea almyra (I)	0	0.0	5	6.7
Chiridotea coeca (I)	0	0.0	3	4.0
Brachidontes exustus (B)	0	0.0	3	4.0
Glycinde nordmanni (P)	2	0.9	0	0.0
Polydora ligni (P)	2	0.9	0	0.0
Nemertinean sp. D	1	0.5	0	0.0
Mysidopsis bigelowi (M)	0	0.0	1	1.3
Total	212	99.0	73	97.3
Total For All Species	214	100.0	75	100.0

Table 18. Macrofaunal total and percentage abundance data for each of the major taxa collected at stations within the existing channel to Georgetown (Stations CW09 and CW11), and at stations along the proposed western channel turning basin (Stations CW10 and CW12).

	STATIONS CW09 AND CW11		STATIONS CW10 AND CW12	
TAXON	Total Abundance	Percentage of Total Faunal Abundance	Total Abundance	Percentage of Total Faunal Abundance
Nemertinea	0	0.0	7	2.4
Nematoda	3	2.5	0	0.0
Mollusca (Class: Bivalvia)	37	30.8	32	11.0
Annelida (Class: Polychaeta)	61	50.8	225	77.3
Annelida (Class: Oligochaeta)	8	6.7	15	5.2
Arthropoda (Class: Crustacea)	-	-	-	-
Order: Mysidacea	1	0.8	1	0.3
Order: Isopoda	4	3.3	8	2.7
Order: Amphipoda	5	4.2	1	0.3
Order: Decapoda	1	0.8	1	0.3
Arthropoda (Class: Insecta)	0	0.0	1	0.3
Total	120	99.9	291	99.8

Comparison of Faunal Assemblages at Dredged and Undredged Stations in Winyah Bay:

Macrofaunal assemblages at two sites within the existing channel to Georgetown (CW09 and CW11) were compared with those at two sites along the proposed Western Channel turning basin (CW10 and CW12). Total and percentage abundance data for each of the major taxa collected at these four stations reflect a difference in sediment type between dredged and undredged stations within the Bay (Table 18). Polychaete annelids represented an overwhelming 77.7% of the fauna at the two undredged stations (C10 and C12) which were characterized by their clayey sediments. The two top-ranking numerical dominants here were the polychaetes *Paraprionospio pinnata* and *Streblospio benedicti* (Table 19). Bivalve molluscs ranked a distant second comprising only 11.0% of the macrofauna at these two stations. Aside from a few small mussels (*Brachidontes exustus*), this taxon was represented by a single species, *Mulinia lateralis*. This filter feeding bivalve is adapted to living in muddy sediments by virtue of its low bulk density afforded by its thin shell, allowing it to remain near the surface (Thayer, 1975).

Polychaetes also represented the greatest proportion (50.8%) of the macrofauna at channel stations CW09 and CW11; however, bivalves comprised a considerably greater proposition (30.8%) of the total faunal abundance here than they did at stations CW10 and CW12. The two top-ranking numerical dominants at stations CW09 and CW11 were the polychaete *S. benedicti* and the bivalve *Tellina versicolor* (Table 20). The more equitable distribution of individuals between the two major taxa may be attributed to the sandier sediments at stations CW09 and CW11. Such sediments are generally more conducive to colonization by filter-feeding organisms.

elsewhere. This species group is characterized by its very high constancy and fidelity at site group 1 and by its moderate constancy at site groups 5 and 6.

Species group C consists of several euryhaline marine and estuarine species which are generally ubiquitous but more common or abundant in mud. Two of these species (P. pinnata and M. lateralis) have been cited as "euryhaline opportunists" (Boesch et al., 1976) which are typically more abundant in mesohaline and polluted or disturbed polyhaline habitats. Species group C exhibited very high constancy at site group 2 and moderate to high constancy elsewhere. Because it is a ubiquitous species group, fidelity values were only moderate to low at those stations where its members occurred.

Species group D is comprised of euryhaline marine species (P. longimerus, C. coeca and P. pholadiformis) as well as "euryhaline opportunists" (Streblospio benedicti and Heteromastus filiformis) and estuarine endemics (Chiridotea almyra) which characterize the fauna at stations having a highly variable salinity regime in the lower reaches of Winyah Bay. This species group exhibited high constancy but only moderate to low fidelity at stations in site groups 6 and 7.

Species groups E, F, and G include several infaunal as well as sessile and motile epifaunal species associated with oyster shell and mussels. All three species groups exhibited high to very high constancy and moderate to high fidelity at site group 5. Members of species group E were more abundant at sand station CW05 than elsewhere, while species belonging to group F were more abundant at sandy clay station CW08. Members of species group G were abundant at all three stations in site group 5 (CW05, CW07 and CW06) and were commonly found in all salinity regimes and sediment types throughout the sampling area. The ubiquity of this species group is reflected in its high constancy but only moderate to low fidelity at all site groups where it occurred.

Site groups 6 and 7 are comprised, respectively, of two channel stations (CW09 and CW11) and two stations along the western shore of Winyah Bay (CW10 and CW12) in the upper reach of the benthic sampling area. Salinities in this reach ranged from mesohaline at low tide to euhaline at high tide (Table 1). The natural stress imposed by such a highly variable salinity regime is reflected in the species composition and generally low abundances at stations in these two site groups. Both site groups are characterized by relatively high numbers of two opportunistic polychaetes, Streblospio benedicti and Heteromastus filiformis. Site group 6 is distinguished from site group 7, however, by its higher abundances of those eurytopic species which are more commonly found in sand or muddy sand (e.g. Ancistrosyllis jonesi, Glycera dibranchiata, Tellina versicolor, and Chiridotea coeca); while site group 7 is characterized by higher abundances of those eurytopic species which are more commonly found in mud (e.g. Paraprionospio pinnata, Sigambra tentaculata and Mulinia lateralis).

Species group A is comprised of several stenohaline marine and a few, relatively rare euryhaline marine species. This group exhibited high to very high constancy and fidelity at stations in site groups 1 and 2 and very low constancy and fidelity elsewhere. Some of the stenohaline species are apparently restricted in their distribution by sediment type as well, since they did not occur at muddy channel station CW03. These include the amphipods Trichophoxus floridanus and Pseudplatyishnopus floridanus, the polychaete Aricidea cerruti, the bivalves Tellina alternata and Crassinella lunulata, and the ophiuroids Hemipholis elongata and Amphiodia pulchella.

Species group B includes the more common euryhaline marine and estuarine species which are ubiquitous with respect to both salinity and substrate, but are almost invariably more abundant at sand stations (especially CW01) than also euhaline, but one of which (CW02) is a sandy bank station while the other (CW03) is a muddy channel station. These two stations share a number of species in common with site group 1 (although in lower abundances), but are distinguished from group 1 by high numbers of two opportunistic species, the bivalve *Mulinia lateralis* and, at station CW03, the polychaete *Paraprionospio pinnata*.

Site groups 3 and 4 are each comprised of a single station (CW04 and CW06, respectively) whose depauperate fauna is represented by a few eurytopic species as well as a few species which are limited in their distribution to higher or lower salinity regimes. The species composition suggests that these two stations represent a transition zone between the higher salinity ocean reach and the lower salinity bay reach. The infauna at station CW04 is dominated by the bivalve *Petricola pholadiformis* while the fauna at station CW06 is dominated by two species, the amphipod *Parahaustorius longimerus* and the isopod *Chiridotea coeca*. *P. pholadiformis* is commonly found at shallow depths burrowing in stiff clay such as that characteristic of the substrate at CW04 (Abbott, 1968). *P. longimerus* and *C. coeca* are both common burrowers on sandy bottoms and wave-exposed ocean beaches from the lower intertidal zone to depths exceeding 25 feet (Bousfield, 1973; Schultz, 1969). *P. longimerus* is also abundant in the plankton near inlets and bays (Fox and Bynum 1975).

Site group 5 consists of three stations (CW05, CW07 and CW08) whose salinities range from mesohaline (16.9^{o}/oo) at station CW08 to euhaline (33.3^{o}/oo) at station CW05, and whose sediments range from sand at stations CW05 and CW07 to sandy clay at CW08. The common denominator relating these three stations and accounting for their similar faunal assemblages was the presence of a hard substrate in the form of oyster shell and mussels which, in turn, provided numerous microhabitats for a variety of sessile and motile epifaunal species.

Table 17. (Cont.)

	Site Group 1	Site Group 2		Site Group 3	Site Group 4	Site Group 5			Site Group 6		Site Group 7	
	CW01	CW02	CW03	CW04	CW06	CW05	CW08	CW07	CW09	CW11	CW10	CW12
Odontosyllis longiseta (P)	0	0	0	0	0	36	23	0	0	0	0	0
Panopeus herbstii (D)	0	0	0	2	0	18	19	8	1	0	0	0
Proceraea sp. (P)	0	0	0	0	0	15	17	4	0	0	0	0
Nereis succinea (P)	1	4	1	0	0	204	96	91	2	0	0	0
Melita nitida (A)	2	0	0	1	0	274	123	56	4	0	0	0
Diadumene leucolena (An)	1	0	0	0	1	173	54	86	0	0	0	0
Mediomastus californiensis (P)	13	1	2	1	1	301	18	55	0	0	0	0
Sabellaria vulgaris (P)	1	4	0	1	0	16	31	45	0	0	33	0
Balanus niveus (Ba)	135	0	0	4	0	30	25	18	0	0	0	0
Brachidontes exustus (B)	0	0	0	0	0	5,202	876	3,674	0	0	0	3

Table 14 (cont.)

	Site Group 1	Site Group 2		Site Group 3	Site Group 4	Site Group 5			Site Group 6		Site Group 7	
	CW01	CW02	CW03	CW04	CW06	CW05	CW08	CW07	CW09	CW11	CW10	CW12
Species Group D												
Parahaustorius longimerus (A)	0	0	0	0	34	0	0	0	0	0	0	0
Chiridotea coeca (I)	0	0	0	0	13	0	0	3	2	1	0	3
Petricola pholadiformis (B)	0	0	0	15	0	0	0	18	6	0	0	0
Streblospio benedicti (P)	0	0	0	0	0	16	35	6	35	5	63	18
Heteromastus filiformis (P)	0	0	0	0	0	0	54	0	4	2	4	12
Chiridotea almyra (I)	0	0	0	0	0	0	0	0	0	0	0	5
Macoma balthica (B)	0	0	0	0	0	0	0	0	0	1	1	0
Species Group E												
Polinices duplicatus (G)	0	0	1	0	0	1	0	0	0	0	0	0
Diopatra cuprea (P)	0	3	1	0	0	3	0	0	0	0	0	0
Batea catharinensis (A)	0	5	0	0	0	15	0	0	0	0	0	0
Pseudeurythoe ambigua (P)	0	1	0	0	0	5	0	0	0	0	0	0
Thelepus setosus (P)	0	1	0	0	0	4	1	0	0	0	0	0
Anadara transversa (B)	0	1	0	0	0	1	0	0	0	0	0	0
Urosalpinx cinerea (G)	0	0	0	0	0	3	1	0	0	0	0	0
Anadara ovalis (B)	0	0	0	0	0	4	1	0	0	0	0	0
Erichthonius brasiliensis (A)	0	0	0	0	0	7	1	0	0	0	0	0
Sabellidae (undet.) (P)	0	0	0	0	0	10	2	0	0	0	0	0
Caprella equilibra (A)	0	0	0	0	0	21	2	0	0	0	0	0
Lepidonotus sublevis (P)	0	1	0	0	0	9	2	0	0	0	0	0
Syllis cornuta (P)	3	0	0	0	0	33	1	4	0	0	0	0
Schistomeringos rudolphi (P)	5	0	0	0	0	30	1	2	0	0	0	0
Polydora caeca (P)	0	0	0	1	0	8	4	3	0	0	0	0
Podarke obscura (A)	0	0	0	0	0	12	2	4	0	0	0	0
Crepidula fornicata (G)	0	0	0	0	0	4	2	2	0	0	0	0
Nemertinean sp. C	0	0	0	0	0	6	1	12	0	0	0	0
Uniola serrata (A)	0	0	0	0	0	7	0	1	0	0	0	0
Species Group F												
Crassostrea virginica (B)	0	0	0	0	0	0	28	0	0	0	0	0
Balanus improvisus (Ba)	0	0	0	0	0	0	333	0	0	0	0	0
Prionospio cirrobranchiata (P)	0	1	0	0	0	0	9	0	0	0	0	0
Eteone heteropoda (P)	0	0	0	0	0	6	9	1	0	0	0	0
Turbellaria (undet.)	0	0	0	0	0	2	13	2	0	0	0	0
Corophium tuberculatum (A)	0	0	0	1	0	2	7	1	0	0	0	0
Alpheus normanni (D)	0	0	0	0	0	1	3	0	0	0	0	0
Parapleustes aestuarius (A)	0	0	0	0	0	0	2	2	0	0	0	0
Species Group G												
Pista quadrilobata (P)	0	0	0	1	0	112	8	1	0	0	0	0
Paracaprella tenuis (A)	0	0	0	0	0	97	39	3	0	0	0	0
Mitrella lunata (G)	1	4	1	2	0	121	9	8	0	0	0	0
Molgula manhattensis (T)	0	0	0	0	0	10	34	0	0	0	0	0

leaving shells and rocks exposed. Epifaunal communities were best developed in these areas (e.g. stations CW04, CW05, CW07, CW08).

Despite the relatively high salinity of the area at the seaward end of the entrance channel, few epibenthic species were found at CW01 because of a dearth of hard substrates. Dominant organisms at this site were the echinoderms Mellita quinquesperforata and Astropecten duplicatus, represented by 18 and five individuals, respectively. Both species are relatively abundant on nearshore sandy bottoms along this coast.

Samples at station CW02 were taken adjacent to the entrance channel at a point midway between CW01 and the south jetty. Bottom type at this station was sandy, and a moderate amount of shelly material was collected in the dredge. This provided substrate for a number of sessile species. Sand dollars (Mellita quinquesperforata) were again the most numerous non-colonial invertebrates in the dredge sample, being represented by 21 individuals.

The dredge catch at station CW03 in the entrance channel consisted largely of motile, non-colonial species, including decapods and mollusks. Bottom sediments consisted of soft clay and silt, and little hard substrate was available for sessile species.

Water currents were very strong at stations CW04 and CW05 at the mouth of the bay, and the bottom was hard at both locations. Dredge tows at both stations contained substantial volumes of shell, which provided substrate for several species of barnacles, hydroids, bryozoans, and other epifaunal taxa. Faunal composition was relatively varied and quite similar at the two sites, although mussels were more abundant at CW05.

Species numbers were somewhat reduced further up the bay at stations CW06 and CW07. Mud, clay, and wood chips were collected at CW06, but the epibenthos was relatively sparce. A considerably larger sample, consisting of shells, rocks

(Cooper marl), and mussels (Brachidontes exustus) was obtained at CW07 in the main channel.

A substantial dredge catch, consisting of shells, mud, clay, mussels (Brachidontes exustus), barnacles (Balanus improvisus), and miscellaneous other invertebrate species, was collected at station CW08. The total of 31 species found at this station was second only to the 32 species identified from CW05.

Epibenthic communities were poorly developed at stations CW09, CW10, CW11, and CW12. Low numbers of species are attributable to a combination of salinity stress and paucity of suitable substrates for epifaunal colonization at these stations. Mussels (Brachidontes exustus) were present at stations CW09 and CW10, although they were much less abundant than at CW07 lower in the bay. Only two species were present in the dredge at CW11, and both were motile decapods (Trachypenaeus constrictus and Penaeus setiferus).

DISCUSSION

I. Trawl-Caught Fishes and Decapod Crustaceans:

Wenner et al. (MS) conducted a two-year survey of the fishes and decapod crustaceans in the Winyah Bay estuarine system from January 1977 to December 1978. Their swept-area estimates of density for trawl-caught fishes and decapod crustaceans were based on 20-minute tows made at 2.5 knots with a 6m headrope length net (distance towed = 1.5km). An estimated density of 4.13kg/ha was reported for all tows over the two-year time span. The overall mean fish density was 2.77kg/ha, whereas, decapod density was 1.36kg/ha. Two of their stations were equivalent to two of the present study: YB02 = South Island Reach; Y001 = Western Channel Reach. Wenner et al's (MS) density estimates for fall collections in these areas were: YB02 (a) fishes = 6.39kg/ha; (b) decapods = 0.91kg/ha; Y001 (a) fishes = 2.46kg/ha; (b) decapods = 3.01kg/ha.

The present study gave overall density estimates of 23.591kg/ha for the trawl-caught fauna (decapods = 10.936kg/ha; fishes = 12.655kg/ha). The densities for the South Island Reach (fishes = 26.315kg/ha; decapods = 13.903kg/ha) and the Western Channel Reach (fishes = 5.576kg/ha; decapods = 13.992kg/ha) were much higher than those previously obtained.

There are two possible explanations for the large discrepancies between Wenner et al. (MS) and this study. We used a slightly larger net (7.9m headrope length verses 6m headrope length) equipped with a tickler chain. The tickler chain extends between the doors and stirs up the bottom ahead of the trawl net so that demersal organisms (penaeid shrimp, flatfishes) are made more vulnerable to capture by the trawl gear. This was more efficient than the gear previously used. Another possible rationale is that the previous study was conducted during a period when the area was experiencing extremely cold winters. White shrimp

(P. setiferus) populations were decimated and the abundance of other estuarine organisms may have been adversely affected, as well.

Wenner et al. (MS) collected 77 species of fishes and 20 species of decapods during their 2 year study. Our bottom trawling efforts in the Winyah Bay System, produced a total of 2,798 fishes representing forty-one species from twenty-two families. A total of 4,042 decapod crustaceans and squids was also collected, with representatives from twenty-four species and nine families. The ten most numerous fish species accounted for almost 94% of the overall fish catch, while eight species of decapods comprised 95% of the total decapod catch. In terms of total biomass, ten fish species represented approximately 95% of the fish catch, while five species of decapods represented over 95% of the decapod crustacean catch. Most abundant among the ten numerically dominant fishes were five species of sciaenids (Stellifer lanceolatus, Menticirrhus americanus, Leiostomus xanthurus, Micropogonias undulatus and Bairdiella chrysura). Among the decapod crustaceans, two species of commercial and recreational importance, the white shrimp, Penaeus setiferus, and the blue crab, Callinectes sapidus, ranked first and second, respectively, in terms of total numbers. These two species occupied reciprocal rankings in terms of overall decapod crustacean biomass.

Among the ten most abundant species of fish in the catch, several of the sciaenids (Stellifer lanceolatus, Leiostomus xanthurus, Micropogonias undulatus and Bairdiella chrysura) and the blackcheek tonguefish, Symphurus plagiusa, showed a tendency for the larger individuals of the species to be concentrated downestuary towards more oceanic waters rather than inside Winyah Bay proper. The star drum, Stellifer lanceolatus, a relatively small sciaenid, was by far the most abundant fish in our trawl collections. This agrees with previous findings . Shealy et al. (1974) found S. lanceolatus to be the most abundant demersal fish in their statewide trawl survey of South Carolina estuaries. They found it was most abundant in the lower reaches of estuaries from fall through early winter. Dahlberg and Odum (1970) reported similar findings from Georgia estuarine systems. Gunter (1945) catagorized Stellifer as a species with a "short life history", reaching maturity in the second year of life; he found ripe females measuring 13 cm long. Spawning reportedly occurs along the Atlantic coast from late spring through summer (Welsh and Breder 1923; Hildebrand and Cable 1934). In the present study, S. lanceolatus was taken in greatest numbers in the Western Channel and Ocean reaches over mud and sand substrates, respectively. The modal length value for S. lanceolatus from the Western Channel Reach was 70 mm TL, while a small percentage of larger individuals (115-150 mm TL) was also taken. Two well-defined modal values, 75 and 125 mm TL, characterized the Ocean Reach catch of S. lanceolatus. Similar values were obtained for the South Island Reach catch, although fewer numbers of individuals were taken. These modal lengths agree closely with the values reported by Shealy et al. (1974). Thus, the first group of fishes in our frequency distributions are young-of-the-year, while the second group represents yearlings (age 1+) in their first full year of life. Presumably, many of these yearlings contributed to the spawn during the previous summer.

The blackcheek tonguefish, Symphurus plagiusa, is the most common species of tonguefish along the Atlantic and Gulf Coasts (Ginsburg 1951) and was the second most numerous species in our fish catch. Shealy et al. (1974) reported this species as ubiquitous and present during all months of the year and in all salinity regimes from 0.1 to 34.2°/oo. Despite these findings of its widespread occurrence, S. plagiusa ranked only thirteenth in numerical abundance in the survey conducted by Shealy et al. (1974). In the present study, and one conducted by Dahlberg and Odum (1970) in Georgia estuaries, S. plaguisa ranked second numerically. Perhaps, gear differences account for this disparity.

Spawning of S. plagiusa reportedly occurs in North Carolina waters from May through October with a peak in June (Hildebrand and Cable 1930). Shealy et al. (1974) collected their smallest specimen (ca. 55 mm TL) in September and suggested that it was a young-of-the-year, i.e., a product of that summer's spawn. Our smallest specimens (n=2 at 42 mm TL) were taken in the Western Channel Reach and we concur with their conclusions that these are young-of-the-year S. plagiusa. In the present study, catches of S. plagiusa were greatest in the trawl tows made over the soft substrates of the Western Channel and Ocean reaches. It was virtually absent over the oyster shell bottom of the South Island Reach. Reid (1954) reported similar findings from Cedar Key, Florida where he found S. plagiusa most abundant in channels and deep flats with muddy bottoms. We found a greater percentage of larger individuals in the Ocean Reach. This is in agreement with Gunter's (1945) findings along the Texas coast where the largest specimens were found in salinities greater than 30°/oo.

The oyster toadfish, Opsanus tau, is a common resident of oyster grounds (de Sylva et al. 1962; Dahlberg 1972) and sunken estuarine debris (Gudger 1910); although it is also found over muddy bottoms. It was the third most abundant fish in the catch but ranked first in terms of fish biomass. Greatest catches were made from the oyster reef bottom of the South Island Reach. Shealy et al. (1974) found O. tau present in South Carolina estuaries during most months of the year and in salinities ranging from 2.0 to 34.2°/oo. It ranked a distant twenty-first in terms of abundance, possibly due to a lack of sampling sites over oyster bottom or to the absence of a tickler chain on their trawl gear.

Dahlberg (1972) found O. tau abundant in the lower to mid-reaches of Georgia estuaries and reported it to be almost entirely absent from sandy-bottom habitated due to a lack of sufficient cover. Similarly, we collected only one specimen over the sandy substrate of the Ocean Reach.

In his extensive study of the genus Menticirrhus, Bearden (1963) reported that the southern kingfish, Menticirrhus americanus, was the most abundant of three species of Menticirrhus in South Carolina waters. He noted its importance as a food and sport fish taken both commercially in the shrimp by-catch, gill nets and haul seines, and recreationally by hook and line. Bearden (1963) collected M. americanus over a wide salinity range (6.4 to 34.6 $^{o}/oo$) and over all bottom types. However, the young were most common over muddy, detritus-laden bottoms of marshland waterways, while adults seemed to prefer sandy ocean beaches. He reported a spawning peak during June and July with maturity being attained by males when they are c. 19 (cm long) and by females when they are c. 23 cm long (standard length). In the present study, M. americanus ranked fourth numerically among the total fish catch. It was taken almost exclusively over the soft bottom-types of the Western Channel and Ocean reaches. Small individuals (<140 mm TL) predominated in these areas; however, there was no marked increase in average size downestuary as with some of the other sciaenids taken during the study. Bearden (1963) suggested larger young-of-the-year M. americanus were more abundant downestuary; however, our results are in closer agreement with Hildebrand and Cable (1934) who found the young equally abundant in both "inside" and "outside" waters near Beaufort, North Carolina.

Like the southern kingfish, the spot, Leiostomus xanthurus, is an important commercial and recreational species in South Carolina's coastal zone. Commercially, it is taken in the shrimp by-catch, gill nets and a small haul seine fishery in the northern coastal section of the state. The sport catch of L. xanthurus is made by hook and line and is most intensive in the pier fishery of the northern coastal area (Hammond and Cupka 1977). Dawson (1958) reported that L. xanthurus has a ubiquitous distribution throughout South Carolina's coastal area, being taken over all bottom-types including oyster and shell reefs. He reported the young to be most abundant in coastal rivers and marshlands where muddy bottoms and reduced salinity predominate. Dawson (1958) noted that large schools of spot occur more southward along the coast from September through November. This run of L. xanthurus is the mainstay of the fall commercial and recreational fisheries, and its members eventually spawn in offshore waters during the winter. Spot ranked fifth numerically among fish species in the catch of the present study, while placing third in total fish biomass. Similar rankings were assigned to spot taken in a state-wide survey by Shealy et al. (1974). Most L. xanthurus taken in the present study were collected over oyster bottom in the South Island Reach. Few small individuals were taken in the other reaches. Most of our specimens from the South Island and Ocean reaches exceeded the maximum size for L. xanthurus taken by Shealy et al. (1974). Cursory examination of several of our specimens revealed ripening gonads. Undoubtedly, most L. xanthurus in our collections were members of the coastal pre-spawning run.

The Atlantic croaker, Micropogonias undulatus, is a favorite species of inshore recreational fishermen in South Carolina, while small numbers of M. undulatus also enter into commercial markets. Shealy et al. (1974) ranked it third in numerical abundance and second by weight in their statewide survey of coastal South Carolina. Bearden (1964) cited spawning as taking place in South Carolina coastal waters from October through January. In the present study, M. undulatus was most abundant in the Western Channel and Ocean reaches, while only three specimens were taken from the South Island Reach. Atlantic croaker from the Western Channel Reach were relatively small (modal length = ca. 135 mm TL). Data supplied by Shealy et al. (1974) indicate these were probably young-of-the-year croaker spawned during the previous winter. Specimens from the Ocean Reach were primarily larger M. undulatus (>165 mm TL), most of which would probably have contributed to the upcoming winter spawn.

The hogchoker, Trinectes maculatus, is a euryhaline, year-round resident of South Carolina estuaries (Shealy et al. 1974). In the Winyah Bay System, greatest numbers of T. maculatus occurred over the muddy bottom of the Western Channel Reach. Few individuals were taken at the downestuary sampling sites. Length frequency distributions provided by Shealy et al. (1974) suggest that small T. maculatus from the Western Channel Reach (modal length = ca. 75 mm TL) were probably young-of-the year from the summer spawn.

The Atlantic stingray, Dasyatis sabina, ranked eighth numerically among fishes collected from the Winyah Bay System, however it occupied second position in terms of weight. It is a relatively small, euryhaline ray, abundant in the estuarine systems of the southeastern United States during the warmer months of the year (Schwartz and Dahlberg 1978). Our catches of D. sabina occurred almost exclusively over oyster bottom in the South Island Reach and many of the specimens were mature males. Our findings are in agreement with Bigelow and Schroeder (1953) who reported D. sabina to be most abundant in Texas waters where salinities exceeded $30^{o}/oo$.

Greatest catches of the southern flounder, Paralichthys lethostigma, occurred in the Western Channel Reach, whereas, only three specimens were taken in the South Island and Ocean reaches combined. The southern flounder is an important recreational species in South Carolina (Bearden 1961), while small commercial quantities are taken as part of the shrimp by-catch (Kieser 1976). In North Carolina sounds, Powell (1974) found P. lethostigma preferred mud over sand bottoms and areas of reduced salinity. The results of our study are in agreement with his observations. Powell (1974) also provided extensive length frequency distributions for small P. lethostigma which suggest that most of our specimens taken in the Western Channel Reach were young-of-the-year southern flounder.

The silver perch, Bairdiella chysura, was the tenth most abundant fish taken in the Winyah Bay System. Like Stellifer, it is a relatively small sciaenid with no commercial or recreational importance. Shealy et al. (1974) listed it as euryhaline and present in all major South Carolina estuaries during most months of the year. Most B. chrysura taken in the present study were collected in the South Island Reach. Extensive length frequency distributions provided by Shealy et al. (1974) suggest that most specimens from the South Island Reach (nodal length = ca. 135 mm TL) were young-of-the-year, possibly from a springtime spawn. Longer, and presumably older, B. chrysura were probably yearlings (age 1+).

The fishery for the blue crab, Callinectes sapidus, is the second most valuable coastal fishery in South Carolina (Eldridge and Waltz 1977). The crab pot fishery accounts for a majority of C. sapidus landings in the state, while it is estimated that the winter trawl fishery (December through March) contributes approximately 12% of the annual landings (Eldridge and Waltz 1977). Pot fishery catches increase from May through October with peak catches occurring from July through October. Tagging studies conducted in South Carolina (Fischler and Walburg 1962) and elsewhere (Tagatz 1968) indicate that movements of adult C. sapidus are confined largely to bays, sounds and the lower reaches of estuaries. Eldridge and Waltz (1977) interpreted blue crab movements in South Carolina estuaries in the following manner. Immature females cohabit waters of reduced salinity with males until the female terminal molt in August and September. Adult males remain in brackish waters year round. Adult females move downestuary during September and October to areas of higher salinity, and subsequently migrate to the deepest portions of the lower estuary with the advent of colder weather. In spring these females migrate along the nearshore beaches with peak spawning occurring among this cohort during late May and early June. Studies on C. sapidus in other areas of the East Coast of the United States corroborate this basic life history strategy (Van Engel 1958; Tagatz 1968).

In the present study, C. sapidus ranked first by weight and second numerically among decapod crustaceans in the catch. Our results agree with the findings of Eldridge and Waltz (1977). Adult males occupied the mid-region of the Winyah Bay system (Western Channel Reach), while mature females occurred almost exclusively in the lower, more saline waters of Winyah Bay proper (South Island Reach). Few C. sapidus were taken in the Ocean Reach, while juveniles (<90 mm CW) were abundant in both the Western Channel and South Island reaches.

Penaeid shrimp are the principal fishery resources of coastal South Carolina. Small landings of white shrimp Penaeus setiferus are taken in the fall. The spring _P. setiferus_ harvest is primarily composed of overwintering adults, while the fall harvest consists of young-of-the-year (Calder et al. 1974). The peak harvest of brown shrimp, _P. aztecus_, occurs in South Carolina during the summer months and annual landings sometimes exceed those of white shrimp (Calder et al. 1974). Pink shrimp, _P. duorarum_, are of major commercial importance along the southeastern coast of the United States only in North Carolina.

Calder et al. (1974) reviewed the existing literature on the life history of penaeid shrimp. They reported that spawning occurs in offshore waters. Subsequent shoreward transport of the planktonic larvae is thought to occur by surface water currents. Post-larvae enter the estuarine nursery grounds and usually concentrate in waters less than 1 meter deep. With growth, the juveniles migrate to the deeper waters of the estuary before returning to the sea to participate in the spawn. Results of the present study reflect this movement of larger juveniles towards more oceanic waters. The smallest individuals of _P. aztecus_, _P. duorarum_ and _P. setiferus_ were generally found upestuary, while the largest individuals of all three species were found in the Ocean Reach. _Penaeus setiferus_ was by far the most abundant of all decapod crustaceans taken in the catch and ranked second in terms of total weight of crustacean biomass.

Because of their mobility, most fishes and decapod crustaceans should not experience any direct, adverse impact from dredging. The potential danger of a sediment plume clogging the gills of fishes is seldom realized due to an avoidance reaction which is triggered by the noise of a dredge in operation (C. Wenner, personal communication). A temporary reduction in fish and decapod populations may, however, result from the removal of benthic organisms which constitute the major food resource for demersal fish and crustaceans. This effect should be particularly apparent in the Western Channel reach where the highest numbers of juvenile penaeid shrimp occurred. Abundances would be expected to return to pre-dredging levels as the benthos recolonized denuded substrates.

II. Benthic Ecology

It is apparent from the results of this study that the effects of previous dredging operations on the benthos of Winyah Bay have been incidental to the overwhelming influence of salinity regime and sediment type. Cluster analysis indicated that faunal assemblages were similar at channel and bank stations within each salinity regime, provided the sediment types were comparable. The only obvious difference in species composition which could be attributed to the effects of dredging, was observed at channel station CW03 which, unlike the other two euhaline off-shore stations (CW01 and CW02), had silty-clay sediments and a depauperate fauna dominated by the opportunistic bivalve, *Mulinia lateralis*. Dredging may have lowered current velocities sufficiently to have changed a formerly dynamic, sandy habitat into a relatively quiescent, muddy one. The predominance of sandy substrates at channel stations within the lower reaches of the bay proper, may be due, at least in part, to previous removal of alluvial silt and clay by dredging. More importantly, however, the naturally high current velocities in this relatively constricted portion of the bay, have probably scoured the bottom of fine sediments.

The greatest number of infaunal species occurred at sandy off-shore stations CW01 and CW02. Species diversity is generally higher in sandy habitats than in muddy ones where substrate instability may be aggravated by the activity of deposit feeders. This combination of factors may effectively exclude suspension feeding organisms from silty sediments and, consequently, lower species diversity (Rhoads and Young, 1970).

The faunal assemblage in the ocean reach of the study area conforms with Sander's (1968) description of a "biologically accomodated" community. The stable salinity regime and absence of continual stress imposed by a physically rigorous environment have allowed diversification of the fauna on an evolutionary time scale. The species which characterize such a benign environment are generally long-lived,highly specialized competitors for resources. At the same time, these species are also typically stenotopic, i.e., intolerant of wide variations in environmental parameters. Furthermore, because stenotopic species do not exhibit opportunistic life history strategies which would enable them to recolonize denuded substrates rapidly, these organisms would be expected to be among those which are most severely impacted by dredging operations.

Conversely, the few estuarine species which characterize the infauna in the middle and upper reaches of lower Winyah Bay are typical inhabitants of a "physically controlled" environment (Sander, 1968). Such species are known to be eurytopic with respect to natural variation in the environment and are thought to be both resistant and resilient in response to perturbations induced by human activity, as well (Boesch and Rosenberg, in press). The fewest infaunal species were collected at sandy bank station CW06 where high current velocities and variable salinities have precluded extensive colonization of the substrate. The two dominant species at this station (*Parahaustorius longimerus* and *Chiridotea coeca*) are both well-adapted to the physically dynamic environment of a tidally-scoured entrance channel and should, as opportunistic species, experience rapid recovery following dredging operations, provided the sediment type is not

TAXON	CW01	CW02	CW03	CW04+	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Hepatus pudibundus	3											
Arthropoda (Class: Pycnogonida)												
Tanystylum orbiculare					17							
Arthropoda (Class: Insecta)												
Insecta (undet.)												3
Chaetognatha												
Chaetognatha (undet.)			3									
Echinodermata (Class: Holothuroidea)												
Holothuroidea (undet.)								7				
Echinodermata (Class: Echinoidea)												
Lytechinus variegatus	3											
Echinodermata (Class: Ophiuroidea)												
Hemipholis elongata	10											
Amphiodia pulchella	20	3										
Ophiophragmus septus	3											
Urochordata (Class: Tunicata)												
Molgula manhattensis					33			113				
Chordata												
Branchiostoma caribaeum	100		3									

TAXON	CW01	CW02	CW03	CW04+	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Monoculodes edwardsi									3			
Acanthohaustorius millsi						3						
Gammarus sp. (undet.)				(1)								
Lepidactylus dytiscus												3
Order: Decapoda												
Panopeus herbstii				(2)	60		27	63	3			
Alpheus normanni								10				
Pinnotheres ostreum					13							
Pagurus annulipes	10											
Latreutes parvulus					10							
Acetes americanus		7										
Pinnixa chaetopterana					7							
Pinnixa sayana		3										
Libinia dubia					3							
Automate evermanni										3		
Leptochela serratorbita		3										
Clibanarius vittatus								3				
Lepidopa websteri						3						
Euryplax nitida	3											
Nanoplax xanthiformis	3											

TAXON	CW01	CW02	CW03	CW04+	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Cleantis planicauda		3										
Cyathura polita									3			
Cirolana polita							3					
Order: Amphipoda												
Melita nitida	7			(1)	913		187	410	3			
Paracaprella tenuis					323		10	130				
Parahaustorius longimerus						113						
Caprella equilibra					70			7				
Cerapus tubularis	3	20	50									
Trichophoxus floridanus	67											
Batea catharinensis		17			50							
Corophium tuberculatum				(1)	7		3	23				
Pseudoplatyishnopus floridanus	37											
Erichthonius brasiliensis					23			3				
Unciola serrata					23		3					
Parapleustes aestuarius							7	7				
Argissa sp. (undet.)	13											
Elasmopus levis							13					
Megaluropus sp. (undet.)	7											
Ampelisca abdita								7				

TAXON	CW01	CW02	CW03	CW04+	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Sthenelais limicola			3									
Annelida (Class: Oligochaeta)												
Oligochaeta (undet.)	153				200	3	163	430	23	20	3	30
Arthropoda (Class: Crustacea)												
(Subclass: Cirripedia)												
Balanus improvisus								1,110				
Balanus niveus	450			(4)	100		60	83				
(Subclass: Malacostraca)												
Order: Mysidacea												
Mysidopsis bigelowi	30										3	3
Bowmaniella floridana	3	7				3						
Order: Cumacea												
Oxyurostylis smithi	17	7	7									
Cyclaspis varians	3											
Leucon americanus			3									
Order: Isopoda												
Chiridotea coeca						43	10		7		3	10
Cyathura burbancki	10			(1)	7		3					
Edotea montosa		13	10									
Chiridotea almyra												17

TAXON	CW01	CW02	CW03	CW04+	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Lysidice ninetta					10							
Spiophanes bombyx	10											
Nephtys bucera	7	3										
Drilonereis magna	3								3			
Polydora ligni										7		
Exogone dispar	7											
Prionospio cirrifera	3				3							
Pherusa ehlersi					7							
Terebella pterochaeta					7							
Cirriformia grandis	7											
Streptosyllis arenae	7											
Hypaniola florida					3							
Spio multioculata											3	
Sphaerosyllis pirifera		3										
Eulalia sanguinea					3							
Brania clavata	3											
Paleonotus heteroseta					3							
Haploscoloplos robustus			3									
Parapionosyllis longiserrata	3											
Glycera americana					3							

TAXON	CW01	CW02	CW03	CW04+	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Goniadides carolinae	80	7	3		3		3					
Hydroides dianthus								70				
Glycera dibranchiata	23	7			17				10		3	
Podarke obscura					40		13	7				
Ancistrosyllis jonesi	43							7	7			
Eteone heteropoda					20		3	30				
Polydora caeca				(1)	27		10	13				
Glycinde nordmanni	7		23						13	7		
Lepidonotus sublevis		3			30			7				
Sabellidae (undet.)					33			7				
Aricidea cerruti	23	13										
Prionospio cirrobranchiata		3						30				
Sigambra tentaculata		3	3							27		
Diopatra cuprea		10	3		10							
Thelepus setosus		3			15			3				
Pseudeurythoe ambigua		3			17							
Gyptis vittata	7	3			7							
Tharyx setigera	13				3							
Magelona sp. (undet.)	10		3					3				
Polychaete sp. A	3		7									

Page 3.

TAXON	CW01	CW02	CW03	CW04+	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Macoma balthica										3	3	
Ensis directus	3											
Tellina agilis				(1)								
Dosinia discus	3											
Mercenaria mercenaria								3				
Glycymeris undata	3											
Annelida (Class: Polychaeta)												
Nereis succinea	3	13	3		680		303	320	7			
Mediomastus californiensis	43	3	7	(1)	1,003	3	183	60				
Paraprionospio pinnata	3		393							257		20
Streblospio benedicti					53		20	117	117	210	17	60
Prionospio cristata	543				30		3					
Sabellaria vulgaris	3	13			53		150	103		110		
Pista quadrilobata				(1)	373		3	27				
Heteromastus filiformis								180	13	13	7	40
Odontosyllis longiseta					120			77				
Syllis cornuta	10				110		13	3				
Schistomeringos rudolphi	17				100		7	3				
Proceraea sp.					50		13	57				
Hemipodus roseus	67	13			13		3	3	3			

Page 2.

TAXON	CW01	CW02	CW03	CW04+	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Urosalpinx cinerea					10			3				
Acteocina canaliculata	7											
Polinices duplicatus			3		3							
Calyptraea centralis	3											
Epitonium rupicola			3									
Terebra floridana	3											
Nassarius trivittatus			3									
Turbonilla interrupta	3											
Anomia simplex					3							
Mollusca (Class: Bivalvia)												
Brachidontes exustus					17,338		12,245	2,920				10
Mulinia lateralis		150	5,136							53	7	33
Crassinella lunulata	430	20										
Petricola pholadiformis				(15)			60		20			
Tellina versicolor	10	3			3				30		63	
Crassostrea virginica								93				
Tellina alternata	53											
Anadara ovalis					13			3				
Barnea truncata				(2)								
Anadara transversa		3			3							

TAXON	CW01	CW02	CW03	CW04^{+}	CW05	CW06	CW07	CW08	CW09	CW10	CW11	CW12
Cnidaria (Class: Anthozoa)												
Diadumene leucolena	3				577	3	287	180				
Haloclava producta					13							
Actiniaria (undet.)	3											
Platyhelminthes (Class: Turbellaria)												
Turbellaria sp. (undet.)					7		7	43				
Nemertinea												
Nemertinean sp. A	133											20
Nemertinean sp. C					20		40	3				
Nemertinean sp. D	3	7	7		7		7	3		3		
Nemertinean sp. B								17				
Nematoda												
Nematoda (undet.)	53								7		3	
Brachiopoda (Class: Inarticulata)												
Glottidia pyramidata	3											
Mollusca (Class: Gastropoda)												
Mitrella lunata	3	13	3	(2)	403		27	30				
Crepidula fornicata					13		7	7				
Natica pusilla	17											
Odostomia impressa								13				

APPENDIX 1

Species of macroinvertebrates collected at each of 12 stations in the Winyah Bay area, and their estimated densities in numbers m^{-2}. Estimates were based on three+ 0.10 m^2 Van Veen grab samples taken at each of the stations.

+Densities reported for station CW04 represent the total number of individuals taken in a single grab sample with surface area = 0.10 m^2. No attempt was made to extrapolate these values to provide estimates in numbers m^{-2}. See text for explanation.

should probably be done during the winter when COD and BOD levels are lower due to colder water temperatures and reduced biological activity. Furthermore, dredging during the winter months would not be expected to interfere with the migration and spawning of fishes.

sediments by infaunal invertebrates is rapid and relatively complete within 6 to 18 months following dredging operations (Van Dolah et al., 1979; Harrison et al., 1964; Kaplan et al. 1974, 1975; Rosenberg 1977). This speedy recovery is a consequence of the high fecundity, rapid growth, short generation time, and flexible reproductive strategies which characterize the life histories of many estuarine species.

A less transient effect of dredging which could be of particular import in lower Winyah Bay, would be the removal or burial of hard substrates in the form of oyster shell and rock which currently provide surfaces for attachment by several epifaunal species. Other modifications of benthic habitats could result from changes in the hydrography of Winyah Bay. Channel-deepening could alter the salinity regime by increasing the extent of saltwater intrusion upestuary (May, 1973). Dredging has also been demonstrated to result in decreased current velocities (Kaplan et al., 1974, 1975) which in turn have led to increased sedimentation rates and a consequent change in benthic community structure. Similar findings have been reported in this study.

Increases in turbidity and decreases in dissolved oxygen concentration related to the resuspension of bottom sediments would not be expected to seriously impact the biota of Winyah Bay since these effects have been demonstrated in other studies to be very localized and transient in nature. Furthermore, unlike some estuaries which are chronically oxygen-stressed (e.g. the York River estuary, Virginia (Boesch et al., 1976)), the Winyah Bay system has dissolved oxygen concentrations which are generally at or near saturation levels (Johnson, 1970). This suggests that a temporary reduction in D.O. would not be as critical in Winyah Bay as it might be elsewhere. Nevertheless, in order to minimize the potential impact of induced oxygen depletion, dredging resettling sediments cover hard substrates or such substrates are entirely removed, epifaunal communities would probably be sparse. Since the epifauna is already poorly represented in the areas sampled upestuary from CW08, little adverse impact from dredging would be expected here. Finally, dredging the entrance channel should have only a modest impact on epifaunal organisms, again because of the nature of the substrate and current scarcity of epifauna.

III. Summary and Review of Dredging Effects

Several authors have reviewed the potential effects of dredging on aquatic ecosystems (Kaplan et all, 1974, 1975; May, 1973; Trisko et al. 1972). Direct adverse effects are generally limited to the removal and burial of benthic organisms and critical habitat. Indirect effects include decreased primary productivity resulting from an increase in turbidity and a consequent decrease in light penetration; decreased dissolved oxygen concentrations resulting from the resuspension of organic matter which can increase both COD and BOD levels while decreasing photosynthetic activity; a decrease in water quality resulting from the resuspension of pollutants formerly buried in the sediments; and changes in benthic habitats resulting from altered hydrography and sedimentation rates.

Beneficial effects of dredging have also been cited. Firm spoil piles can provide substrate for oyster spat settlement; primary productivity may increase in response to the release of nutrients from the sediments; bacterial growth may be fostered by aeration of the sediments and resuspension of organic matter; and water quality may actually improve through the adsorption of suspended and dissolved substances on clay and silt-size particles which subsequently settle to the bottom.

The removal of benthos in the path of a dredge is, of course, unavoidable. However, several researchers have found that recolonization of estuarine drastically altered in the process.

Low numbers of infaunal species also occurred at stations in the upper reach of the study area where sediments consisted of hard-packed clay and salinities ranged from mesohaline at low tide to euhaline at high tide. The species which characterize this habitat (e.g., Paraprionospio pinnata, Heteromastus filiformis, and Mulinia lateralis) are generally eurytopic and exhibit opportunistic life history strategies which should enable them to recolonize dredged bottoms rapidly.

The greatest numbers of epifaunal species, collected in both dredge and grab samples, were taken at those stations (CW05, CW07 and CW08) having a hard substrate in the form of shell or rock. These substrates provide a variety of microhabitats for both sessile and motile epifaunal species and may, in addition, provide some infaunal organisms with a refuge from predation by demersal fish and decapod crustaceans. The relatively high species richness at these stations was not invariably reflected in high species diversity values, however, due to the overwhelming dominance by the mussel, Brachidontes exustus. The fewest epifaunal species were collected at stations in the upper reach of the sampling area (CW09, CW10, CW11 and CW12) where a paucity of hard substrates and variable salinities have prevented colonization by all except the most eurytopic species.

Because of their dependence on the presence of a hard substrate, epibenthic assemblages would be most adversely impacted by dredging operations in the lower bay area between stations CW05 and CW08. The degree of recovery would depend upon the nature of the substrate following completion of channel deepening. If suitable substrates are present after dredging, recovery of the epifauna to current levels of diversity and biomass should be rapid. Alternatively, if

APPENDIX 2

Tables A through N: Length frequency distributions for species of fishes and decapod crustaceans collected by bottom trawl at three reaches in the Winyah Bay System, South Carolina in October, 1980.

Table A. Length frequency distribution for *Bairdiella chrysura* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
113-117	1	1	
118-122	1		
123-127	1	2	
128-132	2	5	
133-137	1	4	1
138-142		5	
143-147	1	2	
148-152		2	
153-157		2	
158-162			
163-167			
168-172			
173-177			
178-182		1	
183-187		1	
233-237		1	
Mean Total Length (mm)	129	143	136

Table B. Length frequency distribution for *Paralichthys lethostigma* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach: Western Channel	South Island	Ocean
98-102	1		
103-107	1		
108-112	1		
113-117	3		
118-122	1		
123-127			
128-132	1		
133-137	1		
138-142	1	1	
143-147	2		
148-152	1		
153-157			
158-162	3		
163-167	1		
168-172			
173-177	1		
178-182	2		
183-187			
188-192			
193-197	1		
198-202			
203-207			
208-212	1		
213-217	1		
233-237			1
248-252	1		
253-257			
258-262	2		
263-267	1		
268-272			
273-277	1		
278-282			
283-287	1		
288-292			
293-297	1		
298-302			
303-307			1
333-337	1		
353-357	1		
Mean Total Length (mm)	188	138	271

Table C. Length frequency distribution for *Trinectes maculatus* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
58-62	1		
63-67	3		
68-72	5		
73-77	13		
78-82	10		
83-87	7		
88-92	2	1	
93-97	2	1	
98-102	1		
103-107			2
108-112			1
113-117			1
118-122			
123-127			
128-132	4	1	
133-137	1		
138-142			
143-147			
148-152		1	
153-157			
158-162			
163-167			
168-172			
173-177	1		
Mean Total Length (mm)	85	115	109

Table D. Length frequency distribution for Leiostomus xanthurus collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
113-117	1		
138-142			1
143-147			1
188-192		1	
193-197			1
198-202			
203-207		1	
208-212		1	
213-217		1	2
218-222		5	1
223-227		4	1
228-232		12	2
233-237		8	1
238-242		9	
243-247		7	
248-252		7	
253-257		3	2
258-262		2	
Mean Total Length (mm)	117	235	212

Table E. Length frequency distribution for *Opsanus tau* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
48-52	1		
53-57			
58-62			
63-67			
68-72			
73-77		1	
78-82			
83-87		1	
88-92		3	
93-97		3	
98-102		8	
103-107		5	
108-112	2	7	
113-117		11	
118-122		4	
123-127		2	
128-132		5	
133-137	1	6	
138-142		3	
143-147		3	
148-152	1		
153-157	3	6	
158-162		3	
163-167	2	2	
168-172	1	2	
173-177		1	
178-182		3	
183-187			
188-192	1		
193-197			
198-202		1	
203-207		1	
208-212	1	3	
213-217			
218-222			
223-227			1
228-232		1	
233-237		1	
238-242		2	
243-247			
248-252		1	
253-257		4	

Table E. (continued)

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
258-262		6	
263-267	1	2	
268-272		2	
273-277		3	
278-282		2	
283-287		1	
288-292		4	
293-297		2	
298-302		3	
303-307	1	4	
308-312		5	
313-317		2	
318-322	1	5	
323-327		2	
328-332		7	
333-337		3	
338-342		2	
343-347		3	
348-352		1	
353-357		1	
358-362			
363-367			
368-372		1	
Mean Total Length (mm)	175	207	225

Table F. Length frequency distribution for *Menticirrhus americanus* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
28-32	1		
33-37			
38-42	1		
43-47			
48-52	2		
53-57			1
58-62	2		
63-67	1		
68-72	1		1
73-77	3		1
78-82	4		3
83-87	2		3
88-92	3		3
93-97	5		1
98-102	2		
103-107	3		4
108-112	1	1	2
113-117	1	1	1
118-122	2	1	1
123-127	1		
128-132			
133-137			
138-142	4		1
143-147			
148-152	1		
153-157	2		2
158-162	1		1
163-167			1
168-172	2		
173-177			
178-182	2		
183-187	1		
188-192	1		
193-197	1		1
198-202			
203-207			
208-212			1
213-217	1		
218-222			
223-227	1		
228-232			
233-237			

Table F. (continued)

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
238-242			
243-247	1		
Mean Total Length (mm)	115	114	111

Table G. Length frequency distribution for <u>Micropogonias undulatus</u> collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
118-122	3		1
123-127	3	1	1
128-132	6		
133-137	6	1	
138-142	6		2
143-147	5		
148-152	1		
153-157	1		
158-162			
163-167			1
168-172			3
173-177			2
178-182		1	2
183-187			1
188-192			1
193-197			3
198-202			2
203-207			2
208-212			1
213-217			
218-222			2
223-227			
228-232			1
233-237			1
238-242			2
243-247			1
Mean Total Length (mm)	134	146	190

Table H. Length frequency distribution for *Stellifer lanceolatus* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
28-32	1		
33-37	3		3
38-42	3	1	1
43-47	22	4	4
48-52	30	6	10
53-57	70	15	24
58-62	83	18	37
63-67	105	15	78
68-72	178	17	71
73-77	134	13	75
78-82	93	14	39
83-87	33	8	80
88-92	19	7	62
93-97	5	4	36
98-102		2	16
103-107	1	2	15
108-112		1	7
113-117	2	4	15
118-122	1	6	22
123-127	6	9	45
128-132	3	9	30
133-137	6	10	29
138-142		3	7
143-147		2	1
148-152	2		
153-157		1	
158-162		1	
163-167		1	
Mean Total Length (mm)	70	86	92

Table I. Length frequency distribution for *Symphurus plagiusa* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
38-42	1		
73-77	1		
78-82	2		1
83-87	1		
88-92			
93-97	1		
98-102	2		
103-107	2		1
108-112	4		
113-117	13		1
118-122	29		2
123-127	39	1	15
128-132	43		14
133-137	34		15
138-142	27	1	17
143-147	9		22
148-152	5		10
153-157	3		11
158-162	1		2
163-167			5
168-172			4
173-177			2
178-182	1		2
183-187			
188-192			
193-197			1
Mean Total Length (mm)	128	134	142

Table J. Disc width frequency distribution for *Dasyatis sabina* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Disc Width Interval (mm)	Reach		
	Western Channel	South Island	Ocean
133-137	1		
188-192		2	
193-197		1	
198-202			
203-207		1	
208-212		2	
213-217		1	
218-222		4	
223-227		1	
228-232		5	
233-237		2	
238-242		6	
243-247		1	
248-252		2	
253-257			
258-262			
263-267			
268-272		1	
273-277		4	
278-282			
283-287		2	
288-292		2	
293-297		1	
298-302		1	
303-307		1	
Mean Disc Width (mm)	137	243	-

Table K. Length frequency distribution for *Penaeus setiferus* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
68- 72	8		
73- 77	3	1	
78- 82	4		
83- 87	44	2	
88- 92	62	2	1
93- 97	112	14	
98-102	151	20	2
103-107	213	39	5
108-112	206	37	5
113-117	163	33	3
118-122	111	29	20
123-127	90	27	18
128-132	47	16	24
133-137	23	9	23
138-142	2	9	21
143-147	11	2	20
148-152		3	14
153-157	5	3	5
158-162	4		3
163-167	4	1	7
168-172			7
173-177		2	2
188-192			1
208-212		1	
Mean Total Length (mm)	110	116	136

Table L. Carapace width frequency distribution for *Callinectes sapidus* collected by bottom trawl in three Reaches in the Winyah Bay System, South Carolina in October 1980.

Carapace Width Interval (mm)	Reach		
	Western Channel	South Island	Ocean
23- 27	4	2	
28- 32	5	2	
33- 37	7	5	
38- 42	8	10	
43- 47	11	9	1
48- 52	10	12	
53- 57	10	7	
58- 62	7	6	
63- 67	7	13	
68- 72	5	5	
73- 77	4	6	
78- 82	4	4	
83- 87	8	3	
88- 92	12	3	
93- 97	17	6	
98-102	18	4	
103-107	19	2	1
108-112	19	3	
113-117	22	6	1
118-122	26	2	
123-127	22	2	
128-132	15	6	
133-137	17	8	
138-142	14	11	
143-147	15	21	1
148-152	16	24	
153-157	15	38	
158-162	17	27	
163-167	10	35	
168-172	10	22	
173-177	6	17	
178-182	2	13	
183-187	3	2	
188-192		1	
208-212		1	
Mean Carapace Width (mm)	112	124	101

Table X. Length frequency distribution for Penaeus duorarum collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach: Western Channel	South Island	Ocean
38- 42		1	
43- 47		1	
48- 52		2	
53- 57	1	9	
58- 62	2	11	
63- 67	1	20	
68- 72	1	23	1
73- 77	2	33	2
78- 82	2	29	4
83- 87	3	10	4
88- 92		12	2
93- 97		5	3
98-102		2	1
103-107			1
108-112			
113-117			
118-122			1
Mean Total Length (mm)	73	73	87

Table N. Length frequency distribution for *Penaeus aztecus* collected by bottom trawl at three Reaches in the Winyah Bay System, South Carolina in October 1980.

Total Length Interval (mm)	Reach		
	Western Channel	South Island	Ocean
58- 62	1		
63- 67		2	
68- 72	5	1	
73- 77	9	6	
78- 82	3	3	1
83- 87	1	1	1
88- 92	1	1	
93- 97			
98-102	1		
103-107			1
143-147			1
153-157			1
158-162			3
Mean Total Length (mm)	76	76	130

APPENDIX 3

Table O. Number, mean carapace width, carapace width extremes, bottom temperature and salinity extremes, and primary locations at which 23 decapod crustaceans and 1 squid species were collected by bottom trawl in the Winyah Bay System, South Carolina in October 1980.

Table P. Number, mean total length, total length extremes, bottom temperature and salinity extremes and primary locations at which 41 fish species were collected by bottom trawl in the Winyah Bay System, South Carolina in October 1980.

Table O. Number, mean carapace width, carapace width extremes, bottom temperature and salinity extremes, and primary locations at which 23 decapod crustaceans and 1 squid species were collected by bottom trawl in the Winyah Bay System, South Carolina in October 1980.

Scientific Name	Common Name	Carapace Width (mm) n	x	Extremes	Bottom Temperature Extremes (°C)	Bottom Salinity Extremes (ppt)	Primary Locations in Winyah System
Arenaeus cribrarius	speckled crab	5	77	63- 95	19.4	34.74 - 34.83	Ocean Reach
Callinectes ornatus	ornate crab	37	69	44- 86	19.4 - 19.6	34.74 - 35.10	Ocean Reach
Callinectes sapidus	blue crab	737	117	23-210	18.2 - 22.3	12.70 - 34.74	Western Channel and South Island Reaches
Callinectes similis	lesser blue crab	30	54	26- 93	19.4 - 22.3	13.67 - 35.10	Ocean Reach
Hepatus epheliticus	leopard crab	7	57	36- 77	19.4 - 19.6	34.74 - 35.10	Ocean Reach
Libinia dubia	spider crab	9	35	5- 61	18.2 - 20.5	13.67 - 35.10	Ocean and South Island Reaches
Libinia emarginata	common spider crab	2	47	27- 68	19.4 - 22.3	34.39 - 34.83	Ocean and South Island Reaches
Libinia sp.		2	41	12- 71	19.4	34.74	Ocean Reach
Lolliguncula brevis	brief squid	26	39[a]	27- 60	19.4 - 22.3	34.01 - 35.10	Ocean Reach
Menippe mercenaria	stone crab	2	34	22- 47	22.2	34.01	South Island Reach
Neopanope sayi	mud crab	6	12	9- 18	18.2 - 22.3	13.67 - 35.06	Western Channel and South Island Reaches
Ovalipes ocellatus	lady crab	36	60	26- 85	19.4 - 19.6	34.74 - 35.10	Ocean Reach
Ovalipes stephensoni		55	52	35- 80	19.4 - 19.6	34.74 - 35.10	Ocean Reach
Pagurus longicarpis	hermit crab	3			22.2	34.01	South Island Reach
Pagurus pollicaris	hermit crab	3			19.4 - 19.6	34.74 - 35.10	Ocean Reach
Palaemonetes vulgaris	grass shrimp	17	32[b]	27- 38	18.2 - 22.3	12.70 - 35.06	South Island Reach
Panopeus herbsti	common mud crab	51	18	4- 33	18.2 - 22.3	12.70 - 34.83	South Island Reach
Penaeus aztecus	brown shrimp	43	86[b]	62-160	18.2 - 22.3	12.70 - 35.10	Western Channel Reach
Penaeus duorarum	pink shrimp	189	75[b]	40-118	18.2 - 22.3	13.67 - 35.10	South Island Reach
Penaeus setiferus	white shrimp	1694	117[b]	70-210	18.2 22.3	12.70 35.10	Western Channel Reach
Persephona mediterranea	purse crab	1	22		19.6	35.10	Ocean Reach
Portunus gibbesii	Gibb's swimming crab	681	42	22- 64	18.2 - 22.3	21.92 - 35.10	Ocean Reach
Portunus spinimanus		364	46	23- 88	18.2 - 22.3	21.92 - 35.10	Ocean Reach
Trachypenaeus constrictus	hardback shrimp	77	62[b]	23- 82	19.4 - 22.3	13.67 - 35.10	Ocean Reach

a = mantle length in mm.

b = shrimp total length in mm = tip of the rostrum to tip of the telson.

Table P. Number, mean total length, total length extremes, bottom temperature and salinity extremes, and primary locations at which 41 fish species were collected by bottom trawl in the Winyah Bay System, South Carolina in October 1980.

Scientific Name	Common Name	Total Length (mm) n	x	Extremes	Bottom Temperature Extremes (°C)	Bottom Salinity Extremes (ppt)	Primary Locations in Winyah System
Anchoa hepsetus	striped anchovy	2	96	92-100	19.6	35.10	Ocean Reach
Anchoa mitchilli	bay anchovy	8	51	38- 65	19.4 - 19.6	34.83 - 35.10	Ocean Reach
Archosargus probatocephalus	sheepshead	1	120		18.2	21.92	South Island Reach
Bairdiella chrysura	silver perch	34	140	115-234	18.2 - 22.3	12.70 - 34.83	South Island Reach
Brevoortia tyrannus	Atlantic menhaden	26	150	129-198	19.5 - 22.3	32.02 - 35.10	Ocean Reach
Centropristis philadelphica	rock sea bass	4	170	133-261	19.4 - 21.9	32.02 - 34.74	Ocean Reach
Centropristis striata	black sea bass	5	102	77-118	18.2 - 19.5	21.92 - 35.06	Ocean and South Island Reaches
Chaetodipterus faber	Atlantic spadefish	2	69	48- 90	19.4 - 19.5	34.74 - 35.06	Ocean Reach
Chloroscombrus chrysurus	Atlantic bumper	1	53		19.6	35.10	Ocean Reach
Citharichthys macrops	spotted whiff	4	111	64-147	19.4 - 19.6	34.74 - 35.10	Ocean Reach
Citharichthys spilopterus	bay whiff	6	79	66- 90	19.6 - 21.9	12.70 - 35.10	Western Channel Reach
Conger oceanicus	conger eel	1	488		22.3	34.39	South Island Reach
Cynoscion nothus	silver seatrout	9	81	60-173	19.4 - 21.0	12.70 - 35.10	Ocean Reach
Cynoscion regalis	weakfish	15	111	91-136	19.4 - 19.6	34.74 - 35.10	Ocean Reach
Dasyatis sabina	Atlantic stingray	41	240[a]	137-305[a]	18.2 - 22.3	12.70 - 34.39	South Island Reach
Etropus crossotus	fringed flounder	17	101	61-151	18.3 - 21.9	12.70 - 35.10	Western Channel Reach
Etropus sp.[b]		2	99	95-104	18.3 - 19.5	21.92 - 35.06	Ocean and South Island Reaches
Gobiesox strumosus	skilletfish	6	61	51- 69	18.2 - 22.3	21.92 - 34.39	South Island Reach
Hypsoblennius hentzi	*feather blenny*	6	81	70- 96	18.2 - 22.3	21.92 - 34.83	South Island Reach
Larimus fasciatus	banded drum	11	59	33- 98	19.4 - 19.6	34.74 - 35.10	Ocean Reach
Leiostomus xanthurus	spot	74	230	117-261	18.2 - 22.3	12.70 - 35.10	South Island Reach
Menticirrhus americanus	southern kingfish	84	114	31-245	18.3 - 21.0	13.67 - 35.10	Western Channel Reach
Menticirrhus littoralis	*gulf kingfish*	3	284	228-316	19.4 - 19.6	34.83 - 35.10	Ocean Reach
Micropogonias undulatus	Atlantic croaker	67	159	118-245	18.2 - 22.3	12.70 - 35.10	Western Channel and Ocean Reaches
Ogcocephalus rostellum	batfish	1	70		19.4	34.74	Ocean Reach
Ophidion marginata	striped cusk-eel	9	155	117-208	18.3 - 21.9	13.67 - 32.02	Western Channel Reach
Opsanus tau	oyster toadfish	71	204	49-370	18.2 - 22.3	12.70 - 35.06	South Island Reach
Paralichthys dentatus	summer flounder	8	183	156-280	18.2 - 21.9	12.70 - 32.13	Western Channel Reach
Paralichthys lethostigma	southern flounder	35	191	102-355	18.2 - 21.9	12.70 - 34.83	Western Channel Reach
Peprilus alepidotus	harvestfish	3	98	86-105	18.3 - 19.4	21.92 - 34.83	Ocean Reach
Prionotus salmonicolor	blackwing searobin	1	72		19.4	34.74	Ocean Reach
Prionotus scitulus	leopard searobin	3	150	55-201	19.4 - 19.6	34.74 - 35.10	Ocean Reach
Prionotus tribulus	bighead searobin	6	42	30- 50	19.6 - 21.9	12.70 - 35.10	Western Channel Reach
Raja eglanteria	clearnose skate	5	259	135-362	19.4 - 19.5	34.74 - 35.06	Ocean Reach
Scophthalmus aquosus	windowpane	17	137	116-166	19.4 - 22.3	12.70 - 35.06	Western Channel Reach
Selene setapinnis	Atlantic moonfish	1	28		19.6	35.10	Ocean Reach
Sphoeroides maculatus	northern puffer	1	158		19.4	34.74	Ocean Reach
Stellifer lanceolatus	star drum	1696	80	30-163	18.2 - 22.2	12.70 - 35.10	Western Channel and Ocean Reaches
Stephanolepis hispidus	planehead filefish	1	45		19.4	34.83	Ocean Reach
Symphurus plagiusa	blackcheek tonguefish	345	133	42-194	18.3 - 22.2	12.70 - 35.10	Western Channel and Ocean Reaches
Trinectes maculatus	hogchoker	58	89	60-176	18.2 - 22.2	12.70 - 35.06	Western Channel Reach

a = *Disc width measurement* = distance between tips of pectoral fins in mm.
b - Undescribed Etropus species; description currently being prepared by Don Stewart, Chicago Field Museum of Natural History.

LITERATURE CITED

Abbott, R. T. 1968. A guide to field identification, seashells of North America. Western Publishing Co., Inc., New York. 280 pp.

Bearden, C. M. 1961. Common marine fishes of South Carolina. Contrib. Bears Bluff Lab. No. 34, 47 pp.

Bearden, C. M. 1963. A contribution to the biology of the king whitings, genus Menticirrhus, of South Carolina. Contrib. Bears Bluff Labs. No. 38, 27 pp.

Bearden, C. M. 1964. Distribution and abundance of Atlantic croaker, Micropogon undulatus, in South Carolina. Contrib. Bears Bluff Labs No. 40, 23 pp.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Western North Atlantic. Part II. Sawfishes, quitarfishes, skates, rays and chimaeroids. Mem. Sears Fdn. Mar. Res. 588 pp.

Bliss, C. T. 1967. Statistics in biology. Vol. I. McGraw-Hill, Inc., N. Y. 558 pp.

Bloomer, D. R. 1973. A hydrographic investigation of Winyah Bay, South Carolina and the adjacent coastal waters. Master's thesis, Georgia Institute of Technology. 57 pp.

Boesch, D. F. 1977. Application of numerical classification in ecological Investigations of water pollution. U. S. Environmental Protection Agency, Ecological Research Report. 114 pp.

Boesch, D. F. 1976. A new look at zonation of benthos along the estuarine gradient, pp. 245-266, In: B. C. Coull (ed.) Ecology of Marine Benthos. University of South Carolina, Columbia.

Boesch, D. F., R. J. Diaz and R. W. Virnstein. 1976. Effects of tropical storm Agnes on soft-bottom macrobenthic communities of the James and York estuaries and the lower Chesapeake Bay. Chesapeake Sci. 17: 246-259.

Boesch, D. F. and R. Rosenberg. (in press). Response to stress in marine benthic communities.

Bousfield, E. L. 1973. Shallow-water Gammaridean Amphipoda of New England. Cornell University, Ithaca, N. Y. 312 pp.

Calder, D. R., P. J. Eldridge and M. H. Shealy. 1974. Description of the resource, p. 4-38, In: Calder, D. R., P. J. Eldridge and E. B. Joseph (eds.), The shrimp fishery of the Southeastern United States: A management planning profile. S. C. Mar. Resour. Ctr. Tech. Rep. No. 5, 229 pp.

Clifford, H. T. and W. Stephenson. 1975. An introduction to numerical classification. Academic Press, New York. 229 pp.

Conservation Foundation. 1980. Winyah Bay reconnaissance study, summary report. Washington, D. C. 75 pp.

Dahlberg, M. D. 1972. An ecological study of Georgia coastal fishes. Fish. Bull. 70(2): 323-353.

Dahlberg, M. D. and E. P. Odum. 1970. Annual cycles of species occurrence, abundance and diversity in Georgia estuarine fish populations. Amer. Midl. Natur. 83(2): 382-392.

Dawson, C. E. 1958. A study of the biology and life history of the spot *Leiostomus xanthurus*, Lacepede, with special reference to South Carolina. Contrib. Bears Bluff. Labs. No. 28, 48 pp.

De Sylva, D. P., F. A. Kalber and C. N. Shuster. 1962. Fishes and ecological conditions in the shore zone of the Delaware River estuary, with notes on other species collected in deeper water. Univ. Delaware Mar. Labs. Infor. Ser., Publ. No. 5, 164 pp.

Eldridge, P. J. and W. Waltz. 1977. Observations on the commercial fishery for blue crabs *Callinectes sapidus* in estuaries in the southern half of South Carolina. S. C. Mar. Resour. Ctr. Tech. Rep. No. 21, 35 pp.

Fischler, K. J. and C. H. Walburg. 1962. Blue crab movement in coastal South Carolina, 1958-59. Trans. Amer. Fish. Soc. 91: 275-278.

Folk, R. L. 1974. Petrology of sedimentary rocks. Hemphills, Austin, Texas. 170 pp.

Fox, R. S. and K. H. Bynum. 1975. The amphipod crustaceans of North Carolina estuarine waters. Ches. Sci. 16(4): 233-237.

Ginsburg, I. 1951. Western Atlantic tonguefishes with descriptions of six new species. Zoologica 36(14): 185-201.

Gudger, E. W. 1910. Habits and life history of the toadfish (Opsanus tau). Bull. U. S. Bur. Fish. 28: 1071-1109.

Gunter, G. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sci., Texas Univ. 1(1): 1-190.

Hammond, D. L. and D. M. Cupka. 1977. An economic and biological evaluation of the South Carolina pier fishery. S. C. Mar. Resour. Ctr. Tech. Rep. No. 20, 14 pp.

Harrison, W., M. P. Lynch and A. G. Altschaeffl. 1964. Sediments of lower Chesapeake Bay, with emphasis on mass properties. J. Sedim. Petrol. 34: 727-766.

Herbich, J. B. 1975. Coastal and Deep Ocean Dredging. Gulf Pub. Co., Houston. 616 pp.

Hildebrand, S. F. and L. E. Cable. 1930. Development and life history of fourteen teleosteon fishes at Beaufort, N. C. Bull. U. S. Bur. Fish. 46: 383-488.

Hildebrand, S. F. and L. E. Cable. 1934. Reproduction and development of whitings or kingfishes, drums, spot, croaker and weakfishes or seatrouts family Sciaenidae, of the Atlantic coast of the United States. Bull. U. S. Bur. Fish. 48(16): 41-117.

Johnson, F. A. 1970. A reconnaissance of the Winyah Bay estuarine zone, South Carolina. S. C. Water Resources Comm. Rep. No. 4. 36 pp.

Kaplan, E. H. et al. 1975. Some factors affecting the colonization of a dredged channel. Mar. Biol. 32: 193-204.

Kaplan, E. H., R. R. Welker and M. G. Kraus. 1974. Some effects of dredging on populations of macrobenthic organisms. Fish. Bull. 72: 445-484.

Keiser, R. K. 1976. Species composition, magnitude and utilization of the incidental catch of the South Carolina shrimp fishery. S. C. Mar. Resour. Ctr. Tech. Rep. No. 16, 54 pp.

Klima, E. F. 1976. A review of the fishery resources in the Western Central Atlantic. Western Central Atlantic Fishery Commission Publ. No 3.

Lance, G. N. and W. T. Williams. 1967. A generalized sorting strategy for computer classifications. Nature 212: 218.

Margalef, R. 1968. Perspectives in ecological theory. University of Chicago Press, Chicago. 111 pp.

May, E. B. 1973. Environmental effects of hydraulic dredging in estuaries. Alabama Mar. Res. Bull. No. 9: 1-85.

Musick, J. A. and J. D. McEachran. 1972. Autumn and winter occurrence of decapod crustaceans in the Chesapeake Bight. Crustaceana 22: 190-200.

Pielou, E. C. 1975. Ecological diversity. John Wiley and Sons, Inc., New York. 165 pp.

Powell, A. B. 1974. Biology of the summer flounder, Paralichthys dentatus, in Pamlico Sound and adjacent waters, with comments on P. lethostigma and P. albigutta. M. S. Thesis, Univ. No. Car., Chapel Hill, 145 pp.

Reid, G. K. 1954. An ecological study of the Gulf of Mexico fishes, in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. Gulf and Carib. 4(1): 1-94.

Rhoads, D. C. and D. K. Young. 1970. The influence of deposit-feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 28: 150-178.

Rosenberg, R. 1977. Effects of dredging operations on estuarine benthic macrofauna. Mar. Poll. Bull. 8: 102-104.

Sanders, H. L. 1968. Marine benthic diversity: a comparative study. Am. Nat. 102: 243-282.

Schultz, G. A. 1969. How to know the marine isopod crustaceans. Wm. C. Brown Co. Publishers, Dubuque, Iowa. 359 pp.

Schwartz, F. J. and M. D. Dahlberg. 1978. Biology and ecology of the Atlantic stingray, Dasyatis sabina (Pisces: Dasyatidae), in North Carolina and Georgia. Northeast Gulf Sci. 2(1): 1-23.

Shealy, M. H., J. V. Miglarese and E. B. Joseph. 1974. Bottom fishes of South Carolina estuaries - Relative abundance, seasonal distribution and length-frequency relationships. S. C. Mar. Resour. Ctr. Tech. Rep. Ser. No. 6, 189 pp.

Strickland, J. D. H., and Parsons, T. R. 1972. A practical handbook of seawater analysis.

Tagatz, M. E. 1968. Biology of the blue crab, Callinectes sapidus Rathbun, in the St. Johns River, Florida. Fish. Bull. 67(1): 17-33.

Thayer, C. W. 1975. Morphologic adaptations of benthic invertebrates to soft substrata. J. Mar. Res. 33: 177-189.

Tiner, R. W. 1977. An inventory of South Carolina's coastal marshes. S. C. Marine Resources Center Tech. Rep. No. 23, 33 pp.

Trisko, R. L. et al. 1972. U. S. Department Port Study, Vol. 4. The Environmental and Ecological Aspects of Deepwater Ports. IWR Report 72-8. U. S. Army Engineer Institute for Water Resources, Alexandria, Virginia. 298 pp.

Van Dolah, R. F. et al. 1979. Effect of dredging and unconfined disposal of dredged material on macrobenthic communities in Sewee Bay, South Carolina. Tech. Rept. No. 39. South Carolina Marine Resources Center. 54 pp.

Van Engel, W. A. 1958. The blue crab and its fishery in Chesapeake Bay, Part I. Reproduction, early development, growth and migration. Comm. Fish. Rev. 20(6): 6-17.

Welsh, W. W. and C. M. Bearden. 1923. Contributions to life histories of Sciaenidae of the eastern United States coast. Bull. U. S. Bur. Fish. 39: 141-201.

Wenner, E. L., W. P. Coon, III, M. H. Shealy, Jr., and P. A. Sandifer. M.S. Species assemblages, distribution and abundance of fishes and decapod crustaceans from the Winyah Bay estuarine system, S. C.

Zeigler, J. M., G. G. Whitney, Jr. and C. R. Hayes. 1960. Woods Hole rapid sediment analyzer. J. Sed. Petrol. 30: 490-495.